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FINAL

CORRECTIVE MEASURES STUDY REPORT SWMU 12/15 - SANITARY LANDFILL/ PESTICIDE DISPOSAL AREA TOOELE ARMY DEPOT TOOELE, UTAH

Contract No. DACA31-94-D-0060
Delivery Order No. 1

Prepared for:

TOOELE ARMY DEPOT
Tooele, Utah 84074

Prepared by:

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Bethesda, Maryland 20814

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MARCH 2003

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March 2003

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ACRONYMS AND ABBREVIATIONS

BRAC	Base Realignment and Closure
CAMU	Corrective Action Management Unit
CAO	Corrective action objective
CAP	Corrective Action Permit
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm/s	Centimeter per second
CMS	Corrective Measures Study
COC	Contaminant of concern
COPC	Contaminant of potential concern
DCD	Deseret Chemical Depot
EPA	U.S. Environmental Protection Agency
EPC	Exposure point concentration
ET	Evapotranspiration cover
FFA	Federal Facility Agreement
ft	Foot
GCL	Geosynthetic clay liner
GM	Geomembrane
HELP	Hydrologic Evaluation of Landfill Performance
HI	Hazard index
HQ	Hazard quotient
IRP	Installation Restoration Program
IWL	Industrial Waste Lagoon
k	Hydraulic conductivity
lb/ft^2	Pound per square foot
MCL	Maximum contaminant level
µg/dL	Microgram per deciliter
µg/g	Microgram per gram

ACRONYMS AND ABBREVIATIONS (cont'd)

µg/L	Microgram per liter
m^2/sec	Square meter per second
NPL	National Priorities List
O&M	Operation and maintenance
OSHA	Occupational Safety and Health Administration
PAH	Polycyclic aromatic hydrocarbon
PPE	Personal protective equipment
RA	Risk assessment
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
Rust E&I	Rust Environment & Infrastructure
SWERA	Site-wide ecological risk assessment
SWMU	Solid waste management unit
TCE	Trichloroethylene
TEAD	Tooele Army Depot
TEAD-N	Tooele Army Depot - North Area
TEAD-S	Tooele Army Depot - South Area
TECA	Tooele Chemical Activity
UAC	Utah Administrative Code
UDEQ	Utah Department of Environmental Quality
USAEC	U.S. Army Environmental Center
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency (now USAEC)
UXO	Unexploded Ordnance
yd^3	Cubic yard

EXECUTIVE SUMMARY

This document is the Corrective Measures Study (CMS) Report for Solid Waste Management Unit (SWMU) 12/15 at Tooele Army Depot (TEAD), Tooele, Utah. SWMU 12/15, known as the Sanitary Landfill/Pesticide Disposal Area, is designated as one of the Known Releases SWMUs. This CMS Report has been prepared for TEAD, in association with the U.S. Army Environmental Center (USAEC), in accordance with the Resource Conservation and Recovery Act (RCRA) Corrective Action Permit (CAP; UT3213820894) issued to TEAD by the State of Utah.

The purpose of the CMS Report is to recommend a corrective measures alternative:

- For SWMUs for which the baseline risk assessment (RA) determined a significant threat to human health under the future residential land use scenario.

  – or –

- For SWMUs that poses a threat to the environment.

According to the State of Utah Administrative Code (UAC) Regulation 315-101-6(c)(3), a site management plan must be prepared for SWMUs that pose a human health cancer risk greater than 1×10^{-6}, a noncancer hazard index (HI) greater than 1.0, or a modeled blood lead level greater than 10 micrograms per deciliter under a future residential land use scenario. The requirement for a site management plan is fulfilled by the CMS Work Plan and this CMS Report.

For SWMUs that pose an unacceptable threat to human health or the environment under current and likely future land use conditions, the CMS evaluates both active corrective measures (i.e., treatment technologies) and management measures. For SWMUs that do not pose an unacceptable threat to human health or the environment under current and reasonably anticipated future land use conditions, the CMS evaluates management measures (e.g., monitoring or deed restrictions) and may consider active corrective measures.

The CMS Report presents a detailed evaluation of the corrective measures alternatives developed in the CMS Work Plan (Dames & Moore, 2000) for the management of identified risks at SWMU 12/15, which was determined in the Phase II RFI (Rust E&I, 1995) to pose human health or environmental risks.

The Known Releases SWMUs CMS Work Plan (Dames & Moore, 2000) identified potential corrective measures alternatives for seven Known Releases SWMUs including the Sanitary Landfill/Pesticide Disposal Area. This was accomplished by developing corrective action objectives (CAOs) for the contaminants of potential concern

(COPCs) in the various media under the likely future land use scenarios. For SWMU 12/15, the likely future land use is to continue its military ownership; the site is maintained but not actively used by the Army.

The CAOs developed in the CMS Work Plan (Dames & Moore, 2000) included quantitative risk-based objectives and qualitative regulatory-driven objectives. COPCs were compared to quantitative CAOs to identify contaminants of concern (COCs). The CMS Work Plan identified corrective measures – which may include treatment technologies or management measures – that meet the qualitative and quantitative CAOs, and assembled them into corrective measures alternatives.

The seven SWMUs identified in the CMS Work Plan were included in a Draft Known Releases SWMUs CMS Report (Dames & Moore, 2000a) issued in February 2000. However, based on discussions between the U.S. Army and State and Federal regulators, the Final CMS Reports for SWMUs 10 and 12/15 are being issued separately to allow for additional data gathering.

The focus of this CMS Report is on the surface and near-subsurface soil at SWMU 12/15. The vadose zone soil at depths ranging from 150 to 200 feet below ground surface have elevated levels of trichloroethylene (TCE) vapor within at least two areas of the landfill. Soil gas can travel significant distances in the permeable soil and the true location of the TCE vadose zone sources is uncertain. This uncertainty along with the large depth to the vertical zone of the elevated TCE vapor suggests that potential engineering controls at the surface would have negligible corrective impact on TCE levels in groundwater. In addition, under current conditions, it is uncertain if TCE is leaching from the vadose zone to the groundwater at levels which result in downgradient migration of TCE in the groundwater. Historical groundwater TCE levels are consistent and the plume appears to be in steady-state. Consequently, the groundwater contamination beneath the Sanitary Landfill will be addressed as part of the SWMU 58 Implementation of Alternative Measures. Therefore, recommendations of this report do not address groundwater (beyond groundwater use restriction and groundwater monitoring) but will not preclude the possibility of future corrective measures for the site groundwater as recommended by the Main Plume corrective action program.

The corrective measures alternatives considered for SWMU 12/15 are listed below:

- Covering the landfill with a multi-layer landfill cap, groundwater monitoring, and land use restrictions to prevent groundwater use and residential development.

- Covering the landfill with an evapotranspiration (ET) landfill cover, groundwater monitoring, and land use restrictions to prevent groundwater use and residential development.

- Making improvements to the existing landfill soil and vegetative cover, groundwater monitoring, and land use restrictions to prevent groundwater use and residential development.

The detailed evaluation of each corrective measures alternative considers technical criteria (including performance, reliability, implementability, and safety), protection of human health, environmental assessment, administrative feasibility, and cost, as outlined below:

- Technical criteria

  – Performance – Evaluates the ability of the alternative to perform its intended function and to meet the CAOs developed in the CMS Work Plan (Dames & Moore, 2000). Factors affecting performance – including site and waste characteristics – are also considered, along with the length of time the alternative maintains its intended level of effectiveness.

  – Reliability – Describes the long-term effectiveness and permanence of each alternative, and evaluates the adequacy of the treatment technology based on performance at similar sites, operation and maintenance (O&M) requirements, long-term environmental monitoring needs, and residuals management requirements.

  – Implementability – Assesses the technical and institutional feasibility of executing an alternative, including constructability, permit and legal/ regulatory requirements, and availability of materials. This criterion also addresses the length of time from implementation of the alternative until beneficial effects are realized.

  – Safety – Considers potential threats to workers, off-post residential communities, and the environment during implementation of the corrective measure.

- Human health assessment – Evaluates the extent to which each alternative protects human health. This criterion considers the classes and concentrations of contaminants left onsite, potential exposure routes, and potentially affected populations. Residual contaminant concentrations are compared to existing criteria, standards, and guidelines.

- Environmental assessment – Evaluates short- and long-term effects of the corrective measure on the environment, including adverse impacts to environmentally sensitive areas.

- Administrative feasibility – Considers compliance with applicable Federal, State, and local environmental and public health standards, requirements, criteria, or limitations.

- Cost – Considers capital and annual O&M costs for each alternative.

Based on the detailed evaluations conducted in this CMS, the ***recommended corrective measures alternative*** for SWMU 12/15 is as follows:

- Improvements to existing soil and vegetative cover, groundwater monitoring, and land use restrictions at the Sanitary Landfill/Pesticide Disposal Area (SWMU 12/15).

Table ES-1 summarizes the corrective measures alternatives evaluated in the CMS for SWMU 12/15; also included are summaries of the results of the human health and ecological RA, potential effects on groundwater, and identified COCs.

The CMS Report addresses how the alternatives reduce exposure to contamination, contaminant concentration, or contaminant migration.

This recommended corrective measures alternative is presented to the public in the Decision Document. Once the recommendations are accepted, TEAD's RCRA Post Closure Monitoring and Corrective Action Permit will be modified to include the approved CMS Report and Decision Document.

TABLE ES-1

Summary of Corrective Measures Alternatives
Sanitary Landfill and Pesticide Disposal Area (SWMU 12/15)

SWMU	Results of Human Health RA (a)						Potential Effects on Groundwater?	Results of Ecological RA (b)	COCs (c)	Corrective Measures Alternatives (including cost) (d)
	Military			Industrial/Construction						
	Cancer Risk	HI	Blood Lead	Cancer Risk	HI	Blood Lead				
Sanitary Landfill/ Pesticide Disposal Area (SWMU 12/15)	1.5×10^{-5}	0.18	NE	1.2×10^{-6}	1.6	NE	Yes	Potential unacceptable risk	Metals, SVOCs, pesticides	Multilayer landfill cap, groundwater monitoring, and land use restrictions ($28,800,000) Evapotranspiration landfill cover, groundwater monitoring, and land use restrictions ($21,200,000) ***Improve existing soil and vegetative cover, groundwater monitoring, and land use restrictions ($3,000,000)***

(a) Based on the Phase II RFI Report (Rust E&I, 1995). In accordance with UAC 315-101, a SWMU requires evaluation of corrective measures if risks, HIs, or blood lead levels under the reasonably anticipated land use scenario exceed 1×10^{-4}, 1.0, or 10 µg/dL, respectively. Maximum risk, HI, and blood level reported.
(b) Ecological RA results from the Site-Wide Ecological RA Report (SWERA; Rust E&I, 1997).
(c) Human health contaminants of concern (COC). Specific COCs are listed in Section 3.0.
(d) The preferred corrective measures alternative for each SWMU is shown in bold italic type.
(e) NE = pathway incomplete or not evaluated; see CMS Work Plan (Dames & Moore, 2000).

1.0 INTRODUCTION

This document is the Corrective Measures Study (CMS) Report for Solid Waste Management Unit (SWMU) 12/15 at Tooele Army Depot (TEAD), Tooele, Utah. SWMU 12/15, known as the Sanitary Landfill/Pesticide Disposal Area, is designated as one of the Known Releases SWMUs. This CMS Report has been prepared for TEAD, in association with the U.S. Army Environmental Center (USAEC), under Alternatives Development and Decision Documents for TEAD – North Area (TEAD-N), Contract No. DACA31-94-D-0060, Delivery Order No. 1. This CMS Report was developed in accordance with Module VII, Corrective Action, of the Resource Conservation and Recovery Act (RCRA) Corrective Action Permit (CAP; UT3213820894) issued to TEAD by the State of Utah Department of Environmental Quality (UDEQ) in February 2002.

1.1 PURPOSE AND SCOPE

The CMS Report represents one of the major steps in the RCRA corrective action process of protecting human health and the environment from the chemicals released at a facility. In accordance with State of Utah guidance, this report is based on the evaluations and conclusions of the Phase II RCRA Facility Investigation (RFI) Report (Rust Environment & Infrastructure (E&I), 1995) and the CMS Work Plan (Dames & Moore, 2000). The RFI delineates the nature and extent of chemical constituents in the environment, and evaluates potential risks to human health and impacts to the environment. The CMS Work Plan identifies site-specific corrective measures alternatives that address the potential risks and hazards at each SWMU.

The purpose of this CMS Report is to analyze the corrective measures alternatives developed in the CMS Work Plan (Dames & Moore, 2000) for SWMU 12/15. This SWMU was determined in the Phase II RFI Report (Rust E&I, 1995) to pose unacceptable risks to human health under the future residential land use scenario, which must be evaluated per Utah Administrative Code (UAC) R315-101-5.2(b)(1). The objective in conducting the CMS is to protect human health and the environment during current and expected future land use. This does ***not*** include cleaning up the facility to standards that apply for other land uses. If other uses are considered in the future, it will be necessary to reevaluate the corrective measures alternatives identified for this SWMU.

The CMS Work Plan identified seven Known Releases SWMUs which posed human health or environmental risks. All seven SWMUs were included in a Draft Known Releases SWMUs CMS Report (Dames & Moore, 2000a) issued in February 2000. However, based on discussions between the U.S. Army and State and Federal regulators, Final CMS Reports for SWMUs 10 and 12/15 are being issued separately to allow for additional data gathering.

The CMS Report is intended to be used in conjunction with the Known Releases CMS Work Plan **(Dames & Moore, 2000);** ***most information presented in the work plan is not repeated in this report***. The CMS Work Plan summarizes TEAD background information, including location, physical characteristics, history, present mission, future use, and previous investigations/regulatory overview. Also included for each SWMU are descriptions of background, summaries of contamination assessment from the Phase II RFI Report (Rust E&I, 1995), results of human health and ecological risk assessments (RAs), interim corrective actions (as applicable), identification of corrective action objectives (CAOs) and contaminants of concern (COCs), qualitative estimates of extent of contamination (as applicable), and development of corrective measures alternatives.

1.2 BACKGROUND

TEAD is located in Tooele Valley in Tooele County, Utah, immediately west of the City of Tooele and approximately 30 miles southwest of Salt Lake City (Figure 1-1). The U.S. Army Ordnance Department established the Tooele Ordnance Depot in 1942. It was redesignated as TEAD-N in August 1962; also at this time, the former Deseret Chemical Warfare Depot was renamed TEAD – South Area (TEAD-S). Both the North and South Areas of TEAD have been major ammunition storage and equipment maintenance installations that support other U.S. Army installations throughout the western United States. In 1996, TEAD-N and TEAD-S were designated as TEAD and Tooele Chemical Activity (TECA), respectively, and placed under separate military command. In October 1996, TECA was renamed the Deseret Chemical Depot (DCD).

The current missions of TEAD are:

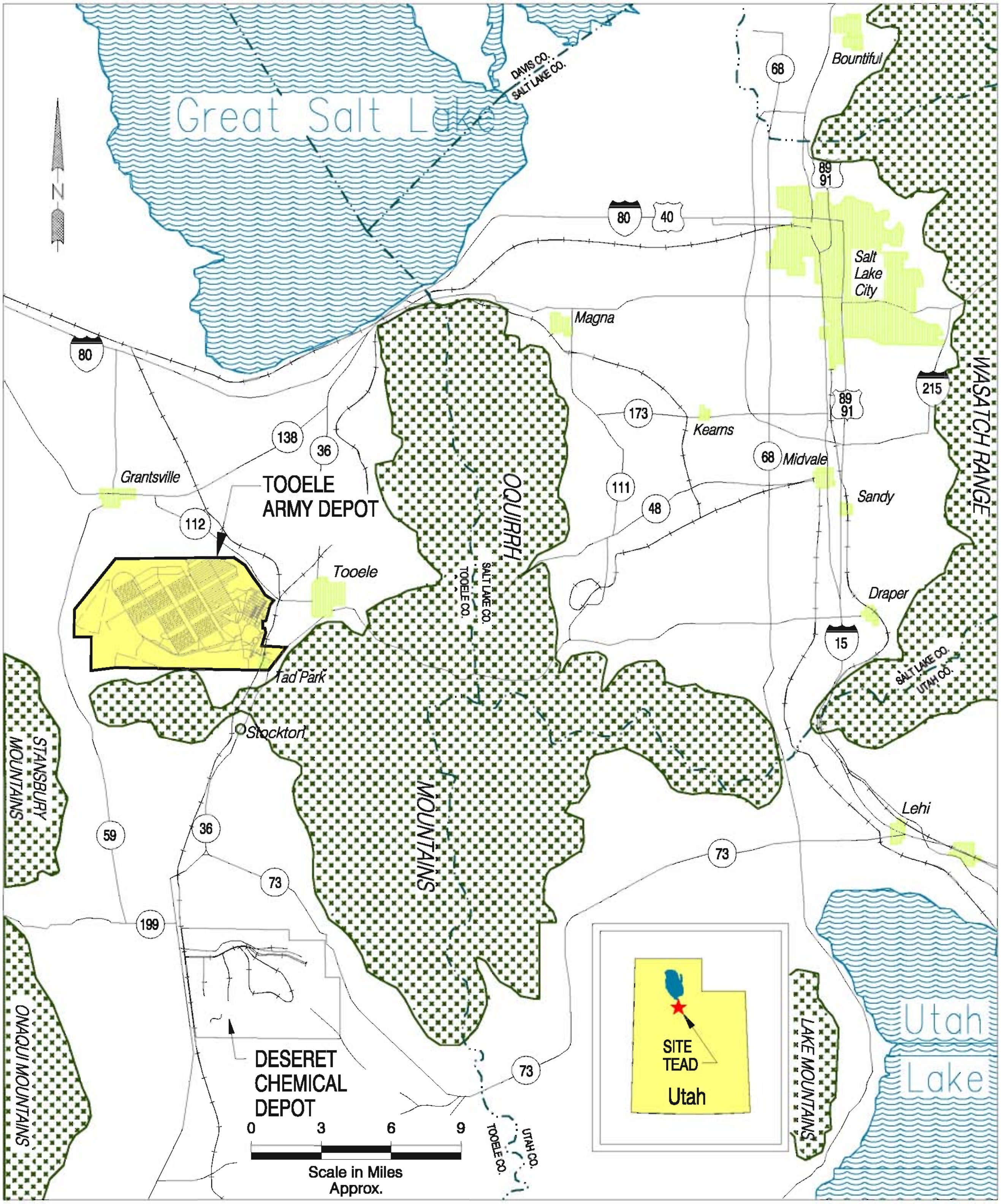
- To receive, store, issue, maintain, and dispose of munitions
- To provide installation support to attached organizations
- To operate other facilities as assigned.

The mission of maintaining and repairing equipment was discontinued in 1995.

Developed features at TEAD include igloos, magazines, administrative buildings, an industrial maintenance area, military and civilian housing, roads, and vehicle storage hardstands and other allied infrastructure. In 1993, TEAD was placed on the list of military facilities scheduled for realignment under the Base Realignment and Closure (BRAC) Program.

As a result of past activities at the installation, TEAD was included in the U.S. Army's Installation Restoration Program (IRP) in 1978. The first component of that program was an Installation Assessment (U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), 1979), which identified a number of known and potential waste and spill sites and recommended further investigations.

In 1984, TEAD was nominated for inclusion on the National Priorities List (NPL) because of identified hazardous constituents at some sites, particularly the Industrial Waste Lagoon (IWL; SWMU 2). However, TEAD was not placed on the NPL until October 1990. In the interim, the U.S. District Court for the State of Utah issued a consent decree to TEAD for groundwater contamination at SWMU 2.



SOURCE: RUST E&I, 1995

FIGURE 1-1
LOCATION MAP OF
TOOELE ARMY DEPOT
AND VICINITY

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As part of being placed on the NPL, a Federal Facility Agreement (FFA) was entered into between the U.S. Army, U.S. Environmental Protection Agency (EPA) Region 8, and UDEQ in September 1991. The FFA addresses 17 SWMUs under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

In January 1991, TEAD was issued a RCRA Post Closure Permit for the IWL (SWMU 2). The permit included a CAP that required action at 29 SWMUs. Additional SWMUs have since been added to the RCRA CAP, which is regulated by UDEQ. The CAP was last updated in February 2002.

Since the initial assessment of TEAD, a number of environmental investigations have been performed under CERCLA or RCRA. At TEAD, environmental investigations have identified 57 sites, including nine designated as the Known Releases SWMUs. These SWMUs are managed under the RCRA CAP program. The Phase II RFI Report (Rust E&I, 1995) determined that seven of these Known Releases SWMUs pose an unacceptable human health risk under the future residential land use scenario. Therefore, according to UAC R315-101-6(c)3, a risk-based closure will not be granted, and a site management plan – the requirements of which are met by a CMS – must be prepared.

This CMS Report discusses the Sanitary Landfill/Pesticide Disposal Area (SWMU 12/15). The Pesticide Disposal Area (SWMU 12) is believed to be located within the Sanitary Landfill (SWMU 15). These SWMUs are discussed together because the exact location of SWMU 12 is unknown but it is entirely encompassed by the former Sanitary Landfill. Figure 1-2 shows the location of SWMU 12/15.

1.3 REPORT ORGANIZATION

The remainder of the CMS Report is organized as follows:

- Discussion of evaluation criteria used in the detailed analysis of corrective measures alternatives (Section 2.0).

- Evaluation of corrective measures, including a Summary of pertinent information presented in the Phase II RFI (Rust E&I, 1995) and the CMS Work Plan (Dames & Moore, 2000) for SWMU 12/15 (Section 3.0). This includes a description of the SWMU; the magnitude and extent of contamination; results of the human health risks and hazards assessment for realistic future uses only; results of the ecological RA; CAOs; COCs; and potentially applicable corrective measures alternatives. Each area-specific corrective measures alternative is evaluated in detail based on the criteria presented in Section 2.0. The alternatives are then compared, and one is recommended for implementation at SWMU 12/15.

- Summary of the recommended corrective measures alternative for SWMU 12/15 (Section 4.0).

- References (Section 5).

- Supporting cost data for each recommended corrective measures alternative (Appendix A).

- Landfill cap/cover detailed alternative analysis (Appendix B).

- Methodology and results of post-corrective measures ecological assessments for SWMU 12/15 (Appendix C).

The Final Additional Field Investigation Report (URS-Dames & Moore, 2001) presents the results of the 1997 additional sampling activities at SWMU 12/15. Groundwater modeling for SWMU 12/15 was presented in Volume III of the Draft Known Releases CMS Report.

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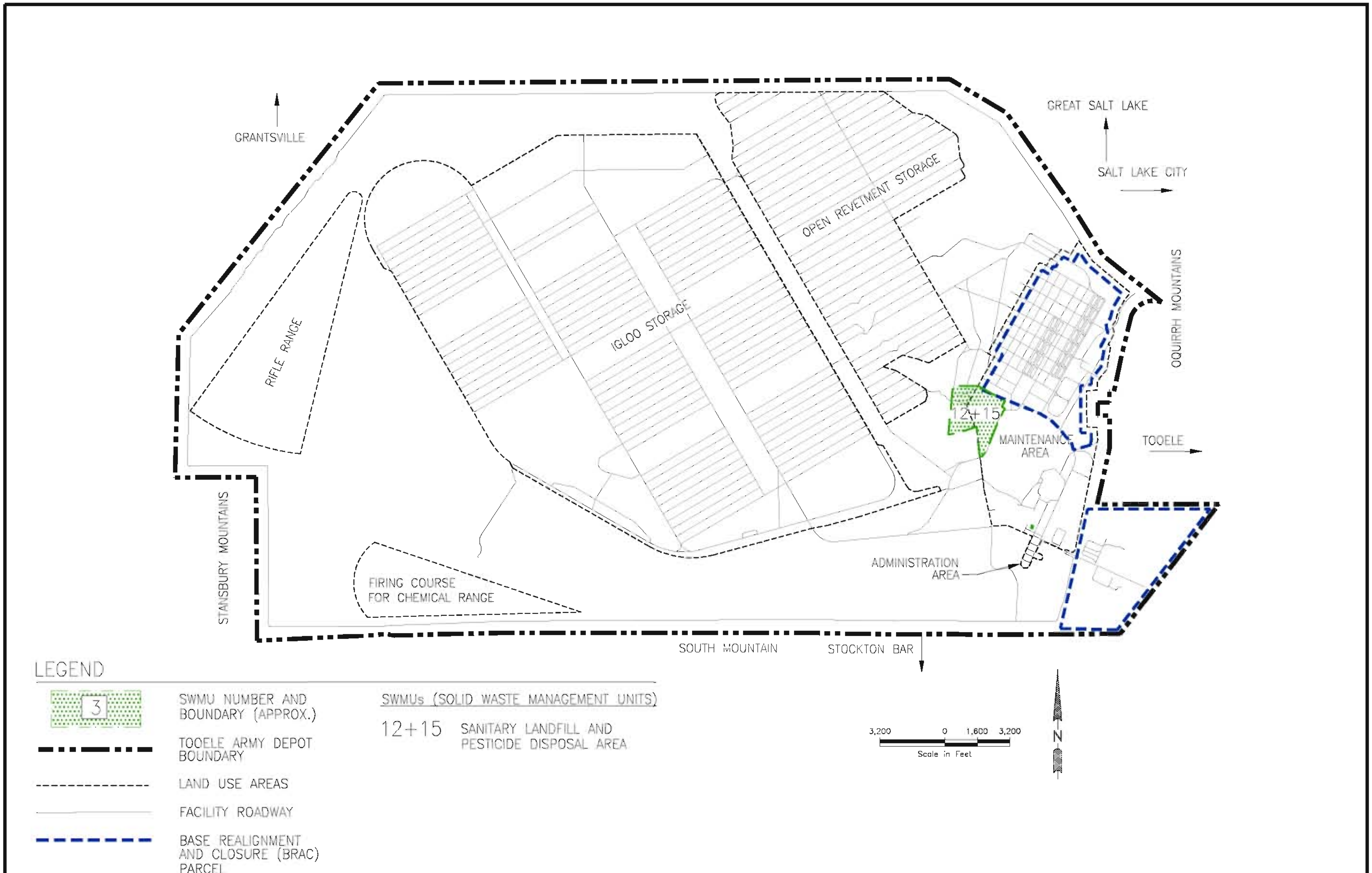

FIGURE 1-2
LOCATION OF SWMU 12/15
TOOELE ARMY DEPOT

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2.0 DESCRIPTION OF EVALUATION CRITERIA

The CMS Work Plan (Dames & Moore, 2000) identifies corrective measures alternatives for SWMU 12/15. Alternatives are identified by developing CAOs for the contaminants of potential concern (COPCs) in the various media under the assumed future land use scenarios.

The CAOs include quantitative risk-based objectives and qualitative regulatory-driven objectives. They are based on land use and potential receptor assumptions, exposure pathways, results of the human health RA, regulatory criteria, and background sample results. The CAOs for SWMU 12/15 are based on the current and likely future military land use. The CAOs were developed in accordance with UAC R315-101, including the "Principle of Non-Degradation"; EPA guidance (USEPA, 1991); the human health RA for the Known Releases SWMUs (Rust E&I, 1995); the Revised Final Site-Wide Ecological Risk Assessment (SWERA; Rust E&I, 1997); and U.S. Army policy (Radkiewicz, 1995). The COPCs are compared to quantitative CAOs to identify COCs.

To determine which contaminants require action, consideration is given to whether average concentrations across the site (i.e., exposure point concentration (EPC) as used in the RA) exceed the CAO, whether COCs are isolated and at low levels, or whether contaminants present unacceptable ecological risks.

Corrective measures – which may include management measures or treatment technologies that meet the CAOs and address the COCs – are assembled into corrective measures alternatives. The alternatives are developed according to RCRA guidance on performing a CMS (Sperber, 1996) and UDEQ regulations. The CMS Work Plan explains the methodology in detail. Figure 2-1 summarizes the alternatives development procedure.

RCRA criteria are used to evaluate each of the corrective measures alternatives identified in the CMS Work Plan. In accordance with RCRA guidance on performing a CMS (Sperber, 1996) and Module VII of the RCRA Part B Permit for TEAD, the detailed evaluation of each corrective measures alternative presented in Section 3.0 considers technical criteria (including performance, reliability, implementability, and safety), protection of human health, protection of the environment, administrative feasibility, and cost, as defined below:

- Technical criteria
  - Performance – Evaluates whether the corrective measures alternative can perform its intended function and meet the CAOs developed in the CMS Work Plan (Dames & Moore, 2000), including compliance with Federal, State, and local regulations. This criterion considers site and waste characteristics, and also the length of time the alternative maintains its intended level of effectiveness.

- Reliability – Describes the long-term effectiveness and permanence of each alternative. This criterion evaluates the adequacy of the corrective measure based on performance at similar sites, operation and maintenance (O&M) requirements, long-term environmental monitoring needs, and residuals management requirements.

- Implementability – Assesses the technical and institutional feasibility of executing a corrective measures alternative, including constructability, permit and legal/regulatory requirements, availability of materials, and length of time from implementation to realization of beneficial effects.

- Safety – Considers the potential threats to workers, nearby communities, and the environment during implementation of the corrective measure.

• Human health assessment – Evaluates the extent to which each alternative protects human health. This criterion considers the classes and concentrations of contaminants left onsite, potential exposure routes, and potentially affected populations. Residual contaminant concentrations are also compared to existing criteria, standards, or guidelines.

• Environmental assessment – Evaluates short- and long-term effects of the corrective measure on the environment, including adverse impacts to environmentally sensitive areas.

• Administrative feasibility – Considers compliance with applicable Federal, State, and local environmental and public health standards, requirements, criteria, or limitations.

• Cost – Considers capital and annual operation and maintenance (O&M) costs for each corrective measures alternative. Capital costs include direct and indirect costs. Annual O&M costs typically include labor, maintenance, energy, and sampling/analysis. For purposes of comparison, costs are presented in terms of present worth (i.e., the current value of a future expenditure). The cost estimates are based on conventional cost estimating guides, vendor information, and engineering judgment. For alternatives with soil excavation and disposal, a preliminary assessment is made concerning whether the soil will be RCRA hazardous as define in 40 CFR Part 261. Appendix A presents the detailed cost estimate tables.

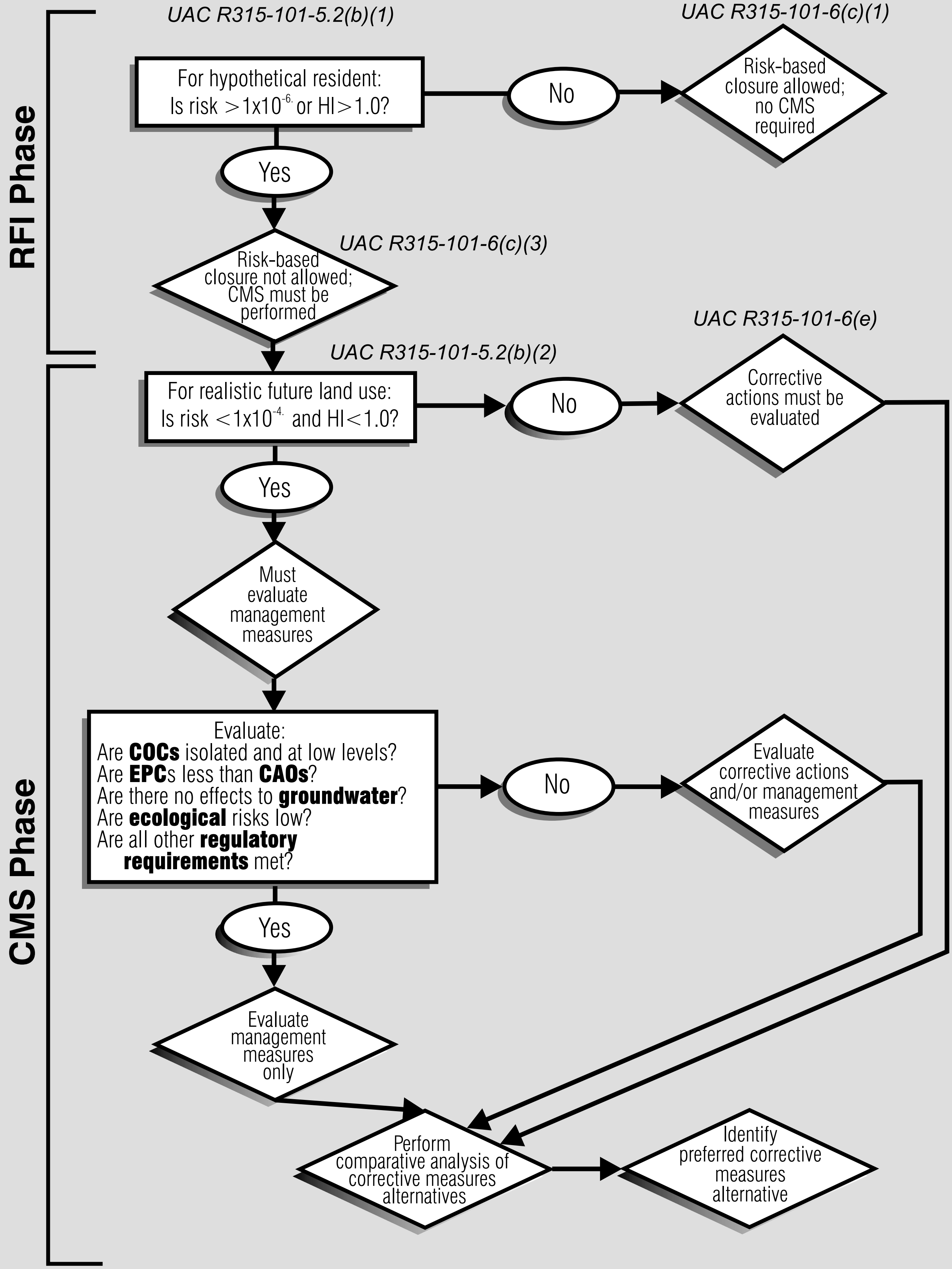

FIGURE 2-1
DEVELOPMENT OF CORRECTIVE MEASURES ALTERNATIVES

09604\056 FIG2-1.CDR (01/03/2000) KD

3.0 EVALUATION OF CORRECTIVE MEASURES

Section 3.0 evaluates corrective measures alternatives for the Sanitary Landfill/Pesticide Disposal Area (SWMU 12/15; Figure 3-1). Data from the CMS Work Plan (Dames & Moore, 2000), the human health RA (Rust E&I, 1995), and the SWERA (Rust E&I, 1997) are also summarized below.

The Sanitary Landfill/Pesticide Disposal Area (SWMU 12/15) covers approximately 70 acres of open land previously used for the land disposal of wastes generated at TEAD (Figure 3-1). According to the Phase II RFI (Rust E&I, 1995), landfilling of wastes at SWMU 12/15 occurred in three main areas – the pre-1960 landfill and inactive evaporation ponds, the post-1960 sanitary landfill, and the construction debris burial area. Wastes were reportedly placed into natural depressions and shallow unlined excavations, and covered with soil. Based on a review in the Phase II RFI (Rust E&I, 1995), wastes were buried in single lifts greater than 8 feet thick. In the north-central portion of the landfill, the thickness of the buried sanitary waste is approximately 30 feet. Test pit records from areas of suspected landfill activity indicate the presence of buried solid industrial and municipal waste throughout the site (Rust E&I, 1995). Battery acid containers, insecticide and herbicide containers, asbestos-containing materials, and ethylene glycol were also reportedly disposed of at SWMU 12/15 (EA, 1988). The Sanitary Landfill was never permitted. Hazardous waste was not deposited in the landfill after October 1980, when TEAD's RCRA Management Plan was implemented.

The major topographic feature of the landfill is an arroyo which bisects the landfill in a north-south orientation. The buried material correlates with the arroyo but becomes wider towards the northwest, which is also the most recent area of landfill burial. The southwest portion of the SWMU contains relatively older buried material. The landfill has a very uneven topography due to the arroyo and earthmoving activities performed in conjunction with landfilling activities. In general, the northern portion of the landfill gently slopes in a southwestern direction towards the arroyo. The southern portion of the landfill is a mix of flat, gently-sloping, and very uneven topography. The arroyo has steep slopes. The surface of the landfill is largely covered by a mix of grasses, forbs, and shrubs. The dominant plant species are cheatgrass, sagebrush, rabbitbrush, sweet clover, and squirrel tail.

The landfill boundary presented in Figure 3-1 is based on an investigation performed in spring 2001 in which trenches were excavated to locate the interface between buried and native material (MWH, 2002). The SWMU 12/15 Exploration Trenching Report (MWH, 2002) identified surface debris at a number of locations within SWMU 12/15. Debris was also identified slightly outside of the SWMU boundary in a small area in the northwest corner of the landfill. This debris will be addressed as discussed in the *Final Work Plan, Revision #2, Interim Removal Action, Sanitary Landfill, SWMU 12/15* (ITSI, 2003). The most commonly identified debris is wood, metal fragments, and concrete, with fewer occurrences of cinder blocks, asphalt, sheet metal, broken glass, pop cans, and foam. The trenching report focused on areas close to the periphery of the landfill, so different debris may be encountered in more central areas of the site. Appendix B presents a more detailed discussion of the existing landfill cover.

Within the west-central portion of the SWMU, a Corrective Action Management Unit (CAMU) is proposed for treatment and final placement of lead contaminated soils from SWMUs 6 and 8. The proposed treatment method is solidification/stabilization. The treated soil will be covered with clean soil. More information regarding the CAMU, soil treatment, and treated soil placement is presented in the Remedial Action Work Plan for SWMU 8 (URS, 2002).

3.1 SUMMARY OF RAs AND CMS WORK PLAN

UDEQ has regulatory decision authority over SWMU 12/15 as part of implementing TEAD's Post Closure Permit. Because the landfill received no hazardous waste after November 19, 1980, Federal and Utah Interim Status Standards for Hazardous Waste Landfills [(40 CFR Part 265) and (UAC R315-7)] do not apply at SWMU 12/15. UAC R315-101 requirements do apply. Appendix B presents additional discussion of regulatory issues for each alternative.

The Phase II RFI (Rust E&I, 1995) identified unacceptable cancer risks and hazard indices (HIs) for the hypothetical future adult and child residents at the Sanitary Landfill/Pesticide Disposal Area. Therefore, according to EPA guidance and UAC R315-101-6(c)(3), this SWMU is included in the CMS process. In addition, elevated HIs were identified for the construction worker. Cancer risks and HIs for Depot workers were identified as acceptable.

Periodic sampling of the groundwater monitoring wells since the late 1980s has detected a plume of trichloroethylene (TCE) beneath the landfill. Historically, the peak concentration of TCE was detected in well N-150-97 and has remained steady at around 200 micrograms per liter (µg/L) over the last five years. Monitoring well C-40 was installed in 2002 in the central area of the landfill near elevated TCE vapor concentrations detected in a vapor sampling well. In 2002, TCE was detected in groundwater at a concentration of 885 µg/L in this well. This high TCE concentration suggests a TCE source near this location, and near surface soil gas sample results supports this. However, the likelihood of identifying the precise location of such a source (if it still exists near the surface) could prove extremely difficult given the heterogeneity of landfilling. The remaining wells at SWMU 12/15 have historically had much lower levels of TCE. In 2002, only two other wells at SWMU 12/15 detected TCE above 10 µg/L; well N-116-88 at 25 µg/L and well N-120-88 at 17 µg/L (Kleinfelder, 2002). The presence of TCE in groundwater is likely related to the landfill activity. The depth to groundwater varies from approximately 200 to 300 feet (ft) at the landfill.

Historical data show antimony concentrations reported in the Fall 1995 groundwater sampling event of over 100 µg/L in unfiltered samples from wells N-120-88 and N-136-90. However, subsequent events have shown levels of antimony to be consistently below or only slightly above the maximum contaminant level (MCL) of

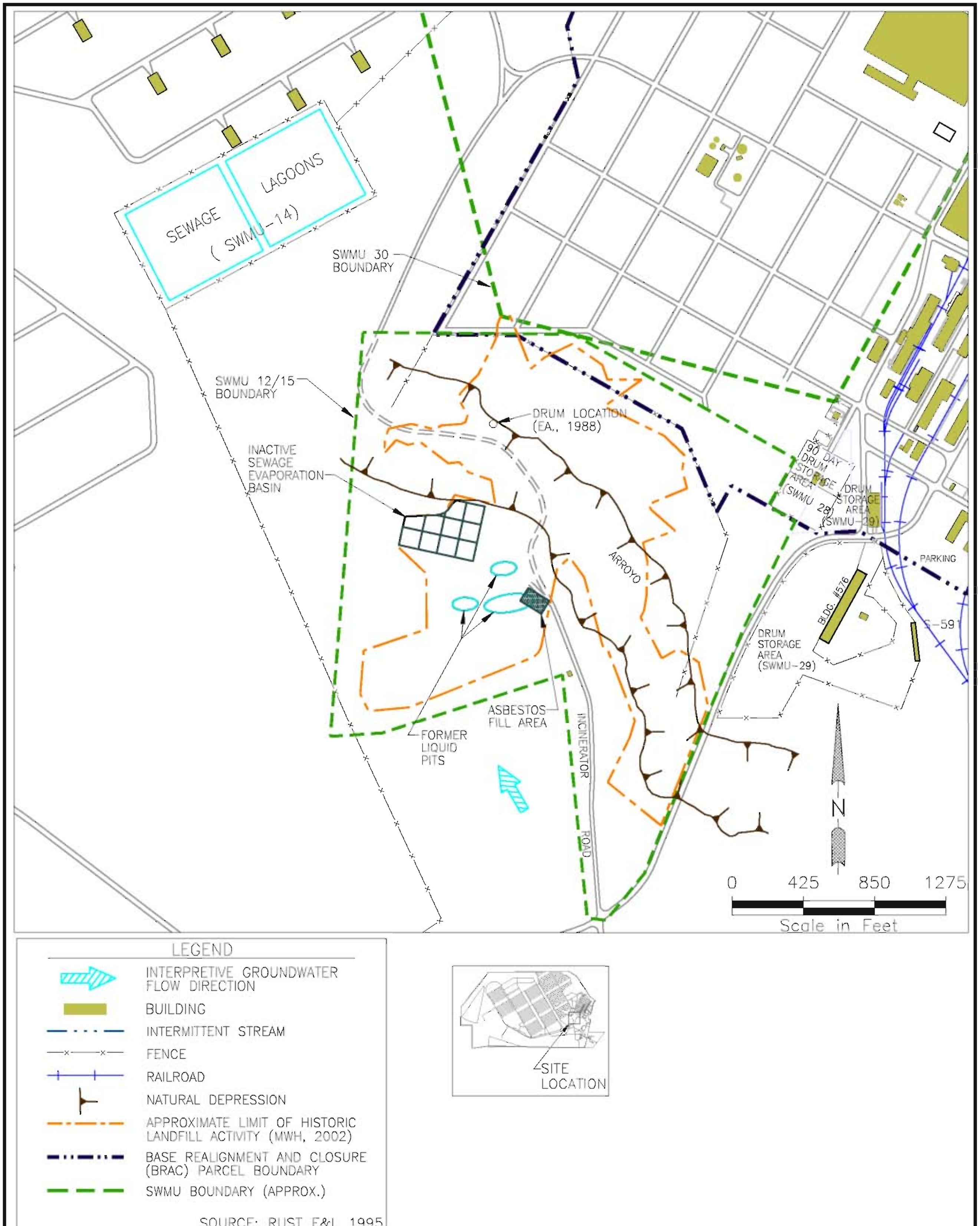

FIGURE 3-1
SANITARY LANDFILL AND PESTICIDE DISPOSAL AREA (SWMU 12/15)
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6 µg/L at SWMU 12/15, suggesting that the antimony concentrations observed in 1995 were likely anomalous and not representative of groundwater (Kleinfelder, 1999). In 2002, only well N-117-88 contained antimony above its MCL with a concentration of 6.4 µg/L. Elevated levels of chromium were also detected in groundwater samples collected from the aquifer beneath SWMU 12/15. The maximum reported concentration in 1997 was 139 µg/L. The elevated concentrations of chromium are likely the result of degradation of the stainless-steel wells, as exhibited elsewhere at TEAD.

The SWERA (Rust E&I, 1997) indicated that SWMU 12/15 is likely to pose unacceptable ecological risks to soil fauna and plants because of elevated concentrations of metals and PAHs. The elevated concentrations of metals in soil also drive the slightly elevated risks to passerines, deer mice, and jackrabbits. However, the risks are derived from contaminants at limited locations. As discussed in Section 3.2, the evaluation of corrective measures alternatives for SWMU 12/15 includes assessment of the ability of each alternative to reduce ecological risks.

The CMS Work Plan (Dames & Moore, 2000) identified COCs by comparing the maximum concentration of each COPC identified in the Phase II RFI Report (Rust E&I, 1995) to its respective quantitative CAO. Based on this evaluation, the COCs for surface soil at SWMU 12/15 are arsenic, chromium, dieldrin, and polycyclic aromatic hydrocarbons (PAHs) including benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and indeno(1,2,3-cd)pyrene. Because a concentration equal to the CAO is equivalent to a cancer risk of 1×10^{-6}, the COCs do not result in unacceptable Depot worker risk levels which are 1×10^{-5}. This conclusion is confirmed by the results of the Depot worker RA, which were acceptable. The COCs identified for subsurface soil at SWMU 12/15 are arsenic, benzo(a)pyrene, and dibenz(a,h)anthracene. Figure 3-2 shows the approximate COC locations in surface and subsurface soil.

TCE was detected in groundwater at SWMU 12/15, at a maximum concentration of 885 µg/L; it is identified as a COC in the CMS Work Plan. Figure 3-3 illustrates the approximate extent of TCE above the MCL of 5 µg/L. However, the results of groundwater modeling show that the TCE plume is approaching steady state and is not predicted to migrate beyond the installation boundary (see Volume III of the Draft Known Releases CMS Report (Dames & Moore, 2000a)). The spring 2002 groundwater sampling round also detected antimony and tetrachloroethene slightly above their MCLs, each in one monitoring well.

In addition to the previously discussed quantitative CAOs, the CMS Work Plan (Dames & Moore, 2000) presented qualitative CAOs for SWMU 12/15 to comply with UAC R315-101, as follows:

- To protect other media from further degradation (i.e., to ensure that levels of contamination do not increase beyond existing levels, per UAC R315-101-3).

- To protect human health and the environment in accordance with Federal, State, and local regulatory requirements.

The focus of this CMS Report is on the surface and near-subsurface soil at SWMU 12/15. The vadose zone soil at depths ranging from 150 to 200 feet below ground surface have elevated levels of TCE vapor within at least two areas of the landfill. Soil gas can travel significant distances in the permeable soil and the true location of the TCE vadose zone sources is uncertain. This uncertainty along with the large depth to the vertical zone of the elevated TCE vapor suggests that potential engineering controls at the surface would have negligible corrective impact on TCE levels in groundwater. In addition, under current conditions, it is uncertain if TCE is leaching from the vadose zone to the groundwater at levels which result in downgradient migration of TCE in the groundwater. Historical groundwater TCE levels are consistent and the plume appears to be in steady-state. Consequently, the groundwater contamination beneath the Sanitary Landfill will be addressed as part of the SWMU 58 Implementation of Alternative Measures. Therefore, recommendations of this report do not address groundwater (beyond groundwater use restrictions and groundwater monitoring) but will not preclude the possibility of future corrective measures for the site groundwater.

The CMS Work Plan presented alternatives for treatment of groundwater. These are no longer considered. In addition, based on discussions between the U.S. Army and State and Federal regulators, an alternative consisting of improvements to the existing soil and vegetative cover has been added for detailed evaluation. Noted below are the three corrective measures alternatives evaluated for SWMU 12/15.

CORRECTIVE MEASURES ALTERNATIVES
Alternative 1: Multilayer landfill cap, groundwater monitoring, and land use restrictions
Construct multilayer landfill cap. Monitor identified contaminants in groundwater. Impose land use restrictions to prevent residential development.
Alternative 2: Evapotranspiration landfill cover, groundwater monitoring, and land use restrictions
Construct evapotranspiration landfill cover. Monitor identified contaminants in groundwater. Impose land use restrictions to prevent residential development.
Alternative 3: Improve existing soil and vegetative cover, groundwater monitoring, and land use restrictions
Improve existing landfill soil and vegetative cover to provide a stable cover over all areas of the landfill. Monitor identified contaminants in groundwater. Impose land use restrictions to prevent residential development.

Table 3-1 summarizes the risks to human health and the environment evaluated in the Phase II RFI (Rust E&I, 1995) and the SWERA (Rust E&I, 1997), and the corrective measures alternatives identified for SWMU 12/15.

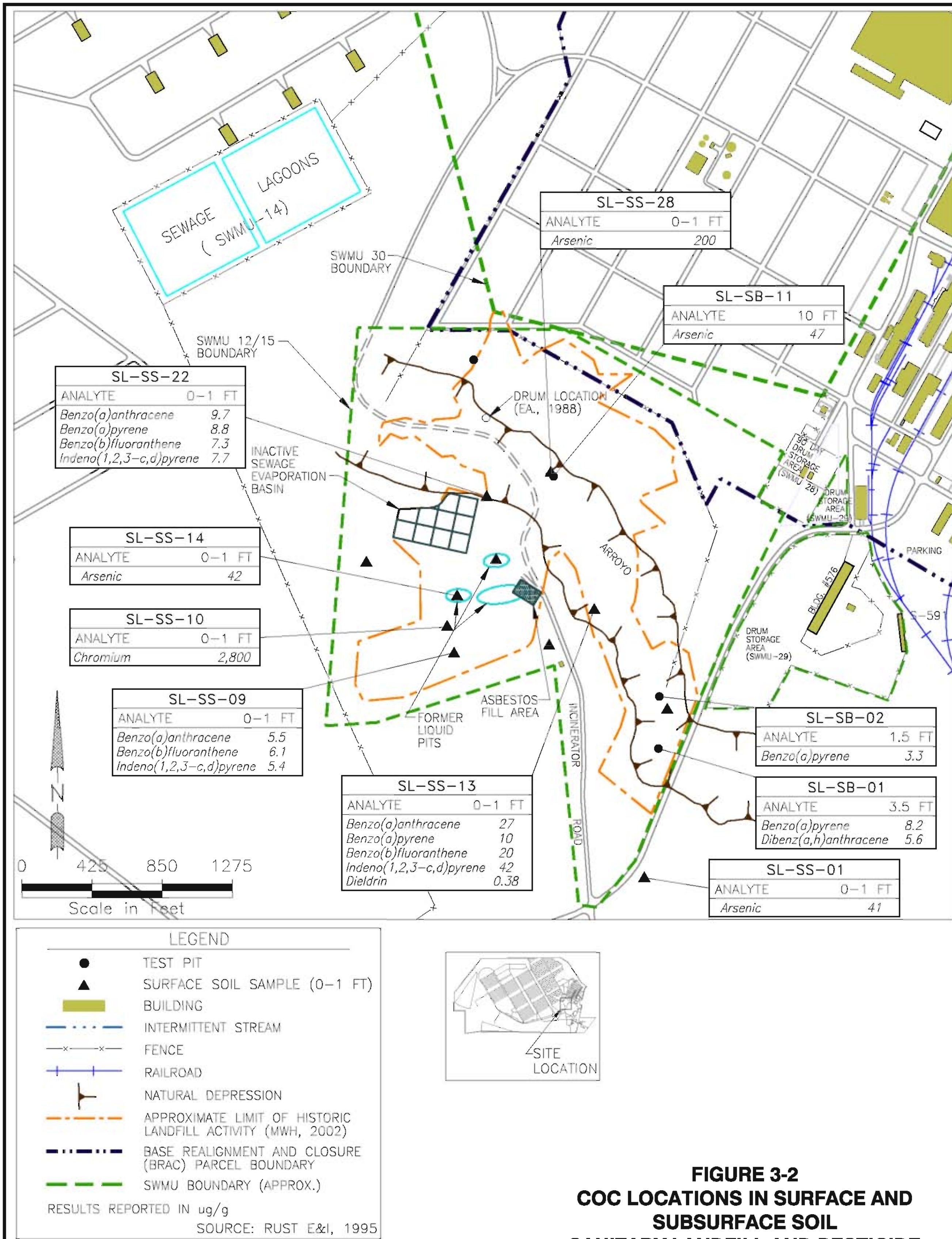

FIGURE 3-2
COC LOCATIONS IN SURFACE AND SUBSURFACE SOIL
SANITARY LANDFILL AND PESTICIDE DISPOSAL AREA (SWMU 12/15)
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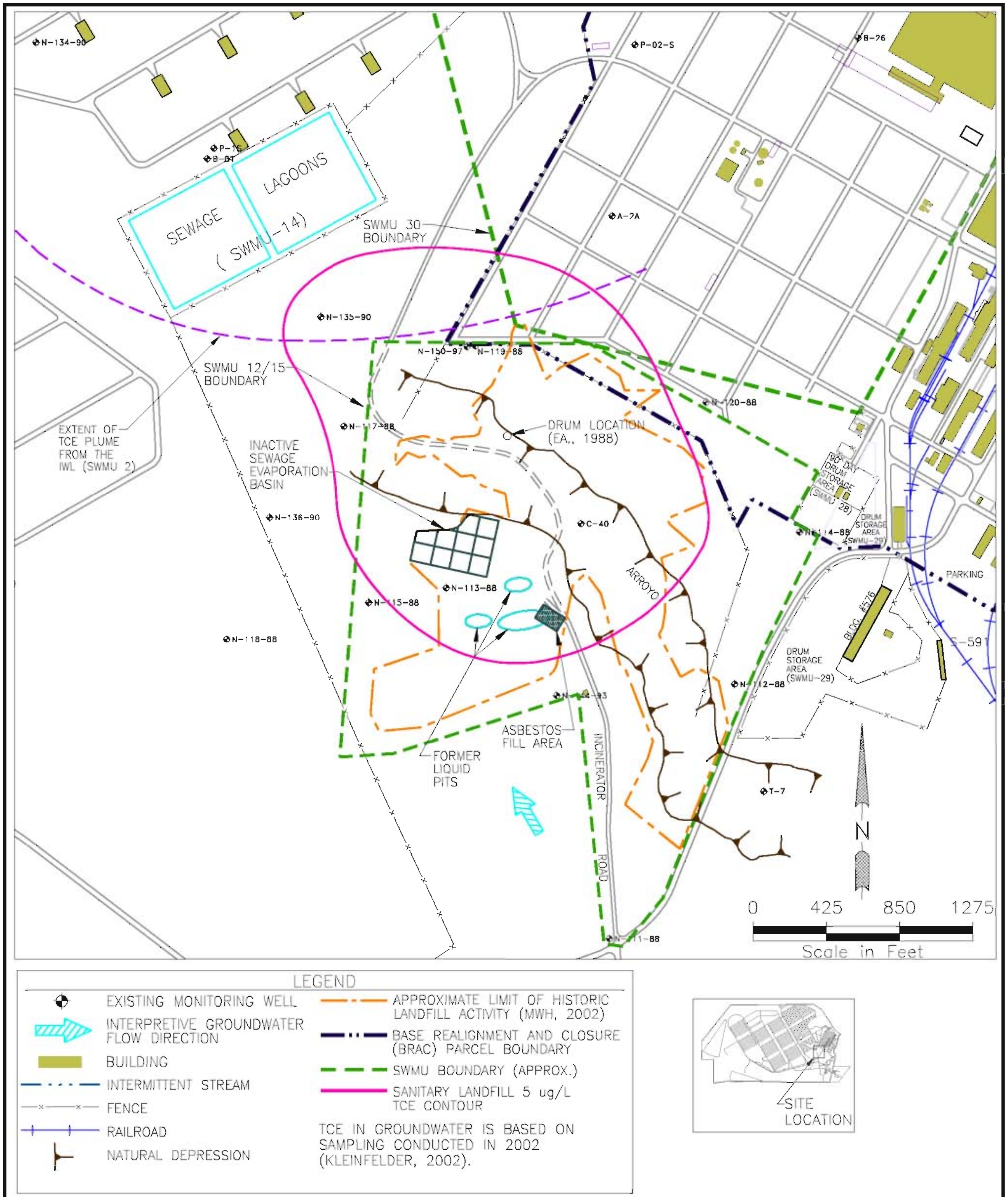

FIGURE 3-3
TCE PLUME
SANITARY LANDFILL AND PESTICIDE
DISPOSAL AREA (SWMU 12/15)
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TABLE 3-1

Summary of Human Health and Environmental Risks
Sanitary Landfill/Pesticide Disposal Area (SWMU 12/15)

Phase II RFI (Rust E&I, 1995)									**SWERA (Rust E&I, 1997)**	**CMS Work Plan (Dames & Moore, 2000) and Volume II, Additional Field Investigation (a)**	
Human Health Risk Assessment (b)								**Impacts to Groundwater**	**Ecological Risk**	**COCs**	**Corrective Measures Alternative (c)**
Residential Land Use Scenario (d)				**Realistic Future Land Use Scenario (e)**							
	Risk	**HI**	**Blood Lead Level (f)**		**Risk**	**HI**	**Blood Lead Level (f)**				
Adult	1.4×10^{-3}	27	NE (g)	Military	1.5×10^{-5}	0.18	NE	Yes	Potential unacceptable risk	Surface soil: Arsenic Chromium (+6) Dieldrin Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Indeno(1,2,3-cd)pyrene Subsurface soil: Arsenic Benzo(a)pyrene Dibenz(ah)anthracene	Multi-layer landfill cap, groundwater monitoring, and land use restrictions Evapotranspiration landfill cover, groundwater monitoring, and land use restrictions ***Improve existing soil and vegetative cover, groundwater monitoring, and land use restrictions***
Child	7.5×10^{-4}	37	NE	Construction	1.2×10^{-6}	**1.6**	NE				

(a) The focus of the CMS Report is on the surface and near-surface soil at SWMU 12/15.
(b) Risks, HIs, and blood lead levels that are above comparison levels appear in bold type.
(c) The recommended corrective measures alternative appears in bold italic type.
(d) EPA guidance and UAC R315-101-5.2(b)(1) require evaluation of the residential land use scenario. Because risks, HIs, or blood lead levels are greater than 1×10^{-6}, 1, or 10 µg/L, respectively, EPA guidance and UAC R315-101-6(c)(3) state that a CMS must be performed.
(e) EPA guidance and UAC R315-101-5.2(b)(2) require evaluation of the realistic future land use scenario. Because HIs are greater than 1, UAC R315-101-6(e) indicates that corrective measures must be evaluated.
(f) Blood lead levels are expressed as micrograms per deciliter (µg/dL) for 95 percent of the population. Centers for Disease Control (CDC) defines a limit of 10 µg/dL for the protection of children.
(g) NE = pathway incomplete or not evaluated; see CMS Work Plan (Dames & Moore, 2000).

3.2 DETAILED EVALUATION OF CORRECTIVE MEASURES ALTERNATIVES

Section 3.2 evaluates the three corrective measures alternatives for the Sanitary Landfill/Pesticide Disposal Area.

The three alternatives evaluate three types of cover protection for buried wastes. Alternative 1 uses a comprehensive multilayer cap. Alternative 2 uses an evapotranspiration (ET) landfill cover. Alternative 3 involves upgrading the existing landfill soil and vegetative cover.

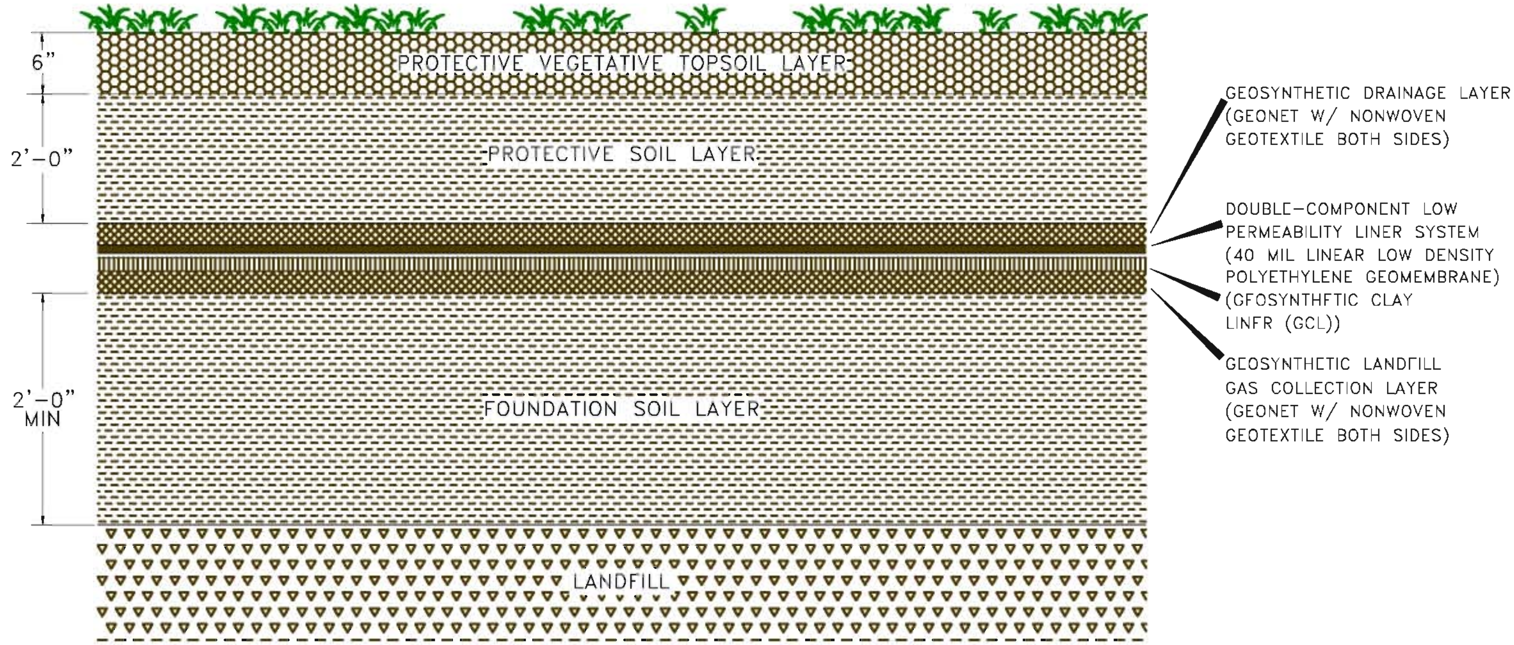
Appendix B presents the detailed landfill cover alternative development, including a regulatory discussion (Section B.1), a review of military landfills (Section B.2), a preliminary evaluation of the landfill soil cover (Section B.3), and the Hydrologic Evaluation of Landfill Performance (HELP) model results (Section B.4). The HELP model was performed to evaluate the relative performance of the different landfill cover and cap designs. It calculates the amount of water that would pass through the bottom layer of a given soil cover or multilayer cap as gallons per unit area per time. The model is limited to relatively simple cases and cannot account for all the intricacies of a specific landfill design. However, the HELP model provides data used to compare the infiltration rates for each landfill design tested, thereby evaluating their relative performance. Section B.5 of Appendix B presents conceptual designs for the three landfill alternatives.

3.2.1 Alternative 1 – Multilayer Landfill Cap, Groundwater Monitoring, and Land Use Restrictions

This alternative involves designing and constructing a multilayer cap at SWMU 12/15 over all areas of buried debris. It also includes groundwater monitoring to determine whether TCE contamination is increasing or moving. Land use restrictions prevent future residential use of the site.

A soil and geomembrane/geosynthetic clay liner (GM/GCL) double-barrier layer cap is proposed to minimize infiltration and the burrowing of animals. Figure 3-4 depicts the proposed cap cross section under this alternative. Appendix A presents the cost estimate and Appendix B presents the conceptual design for the alternative. From top to bottom, the multilayer cap is to be composed of:

- A 6-inch protective vegetative top soil layer designed to minimize cap erosion and to promote drainage off the cap. Section B.3.4.2 of Appendix B discusses the re-establishment of vegetation. The surface shall have slopes of at least 3 percent but not more than 5 percent over most of the capped area. Surface slopes of up to 33 percent will occur for short distances on side slopes near the landfill perimeter;



NOT TO SCALE

NOTE: FOUNDATION SOIL LAYER MAY INCLUDE EXISTING COVER LAYER.

FIGURE 3-4
MULTI-LAYER LANDFILL CAP CROSS SECTION (TYPICAL)
SANITARY LANDFILL AND PESTICIDE DISPOSAL AREA (SWMU 12/15)
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- A 24-inch protective soil layer consisting of soil borrowed from on and off-site. This layer is designed to minimize erosion, accommodate shallow root penetration and freeze/thaw problems, and store infiltrated water for later evaporation;

- A geosynthetic drainage layer to minimize water infiltration into the low permeability layer – composed of geotextile-wrapped geonet with a nominal thickness of approximately one-quarter inch and an in-plane hydraulic transmissivity greater than 3×10^{-5} square meters per second (m^2/sec) and a final slope of at least 2 percent after settlement. This layer is an alternative to EPA guidance for soil drainage layers;

- A double-component (barrier) low permeability liner system located below the frost zone – to provide long-term minimization of water infiltration into the underlying waste – consisting of a 40 mil thick GM placed over a GCL. A GCL is a factory-manufactured hydraulic barrier typically consisting of bentonite clay or other low permeability material, supported by geotextiles and/or geomembranes which are held together by needling, stitching, or chemical adhesives. For the purpose of this evaluation the GCL will consist of approximately 1 pound per square foot (lb/ft^2) of adhesive-bonded granular sodium bentonite sandwiched between an upper primary woven geotextile and a lower secondary open weave geotextile. The installed GCL is assumed to the following properties: a hydraulic conductivity (k) of 5×10^{-9} centimeters per second (cm/s); a thickness of 0.7 inches; and a final slope of at least 3 percent after settlement;

- A geosynthetic landfill gas collection layer to remove soil gases. This layer also consist of geotextile wrapped geonet (see drainage layer description above). The methane will be vented from extraction wells and passive wells;

- A foundation soil layer that is the structural base for the final cover. It includes the soil that covers the buried waste and any additional regrading required to prepare the landfill for construction of the final cover (i.e., smoothing out high relief). Based on the topography and the thickness of buried waste at SWMU 12/15, it is estimated that approximately 600,000 cubic yards (yd^3) of foundation layer soil fill will be required over the limit of the landfill in order to maintain the minimum slope requirement of 3 percent for the cap and to reduce the potential for damage from settlement and subsidence. Approximately one-third of the volume will be excavated from high points within the landfill and moved to low points. The existing vegetation will be stripped and the ground stabilized where necessary before constructing the foundation soil layer. It is assumed unexploded ordnance (UXO) screening of excavated areas will be required.

The HELP model was used to evaluate infiltration rates for the multilayer geosynthetic membrane cap. Appendix B presents the results of this modeling. This design included seven layers: four vertical percolation layers, one lateral drainage layer, one flexible membrane liner, and a geosynthetic membrane liner. The mean monthly infiltration for this scenario is 0.0033 inches per unit area. The percent of the total precipitation infiltrating and reaching the buried wastes is 0.264 percent.

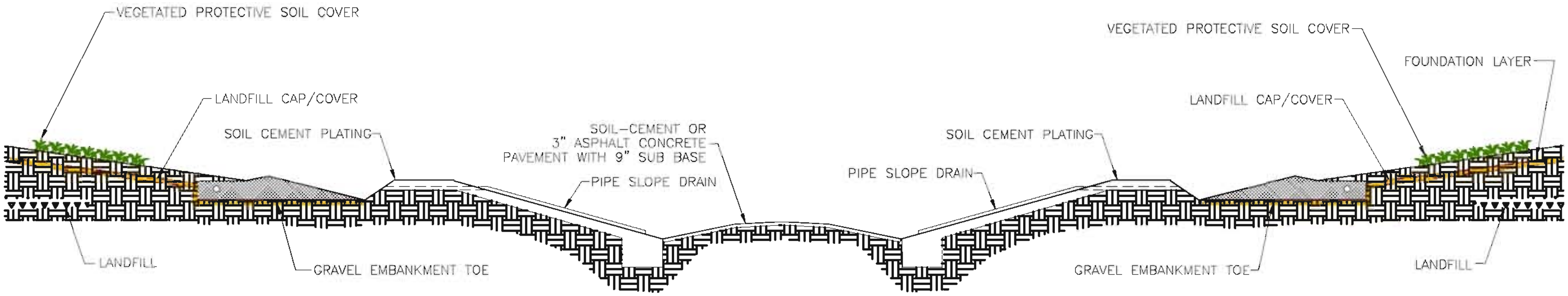
Also included in the landfill cover is a stormwater management system to control runoff from rainfall and snowmelt. A large portion of the landfill cap runoff will flow into the existing arroyo which will be stabilized to prevent infiltration of stormwater, landfill runoff to buried waste, and cap erosion. A stabilized channel of soil-cement cover will channel runoff from the cap to a stable outlet where it can evaporate or flow beyond the cap (see Figure 3-5). This channel will also serve as a structural reinforcing element for the landfill cover on the adjacent hill slopes. The channel is to provide hydraulic capacity for stormwater flow. An additional benefit will be the use of the channel for vehicle access to the interior of the landfill for inspection and maintenance.

A soil-cement channel was selected over the other potential options (asphalt channel and extension of the cap to cover the channel) on the basis of durability, reliability, performance, implementability, and cost. However, the application of a low permeability, low maintenance modified asphalt cover should be investigated as an alternative during the design phase.

The historical extent of the landfill is approximately 70 acres. This entire area will be capped with all of the components discussed above (see Figure 3-6). To be conservative and account for the irregular shape of the landfill, 90 acres is assumed. An additional 30 acres is estimated to be necessary around the cap perimeter to provide a uniform but not excessively steep surface grade from the cap to the surrounding existing ground surface. This additional cover area is assumed not to require the geosynthetic drainage layer, the double-component low permeability liner or the geosynthetic landfill gas collection layer.

It is assumed that sections of the existing landfill can be excavated to establish acceptable surface slopes and to provide a source of foundation soil for fill areas. This assumption is necessary because of the high topographic relief in sections of the landfill. If these sections cannot be excavated due to buried waste, UXO, or other problems, then a potentially large volume of additional fill material will be needed. Potential on-post sources of fill exist, although the adequacy of the material must be tested prior to design. It is assumed that a leachate collection system will not be required as part of the cover design. It is assumed that inspection and maintenance of the cover and surface water system will occur for 30 years. A final assumption is that only moderate surface water flow occurs in the arroyo.

This alternative also includes groundwater monitoring. The current monitoring program at SWMU 12/15 consists of semiannual sampling of wells N-115-88, N-116-88, N-117-88, N-120-88, N-135-90, N-150-97, and C-40. Samples are analyzed for antimony and VOCs. The results are issued in a semiannual report. For the purposes of this CMS, it is assumed that the current monitoring program will continue to be



NOT TO SCALE

FIGURE 3-5
STABILIZED CHANNEL/LANDFILL SECTION
SANITARY LANDFILL AND
PESTICIDE DISPOSAL AREA (SWMU 12/15)
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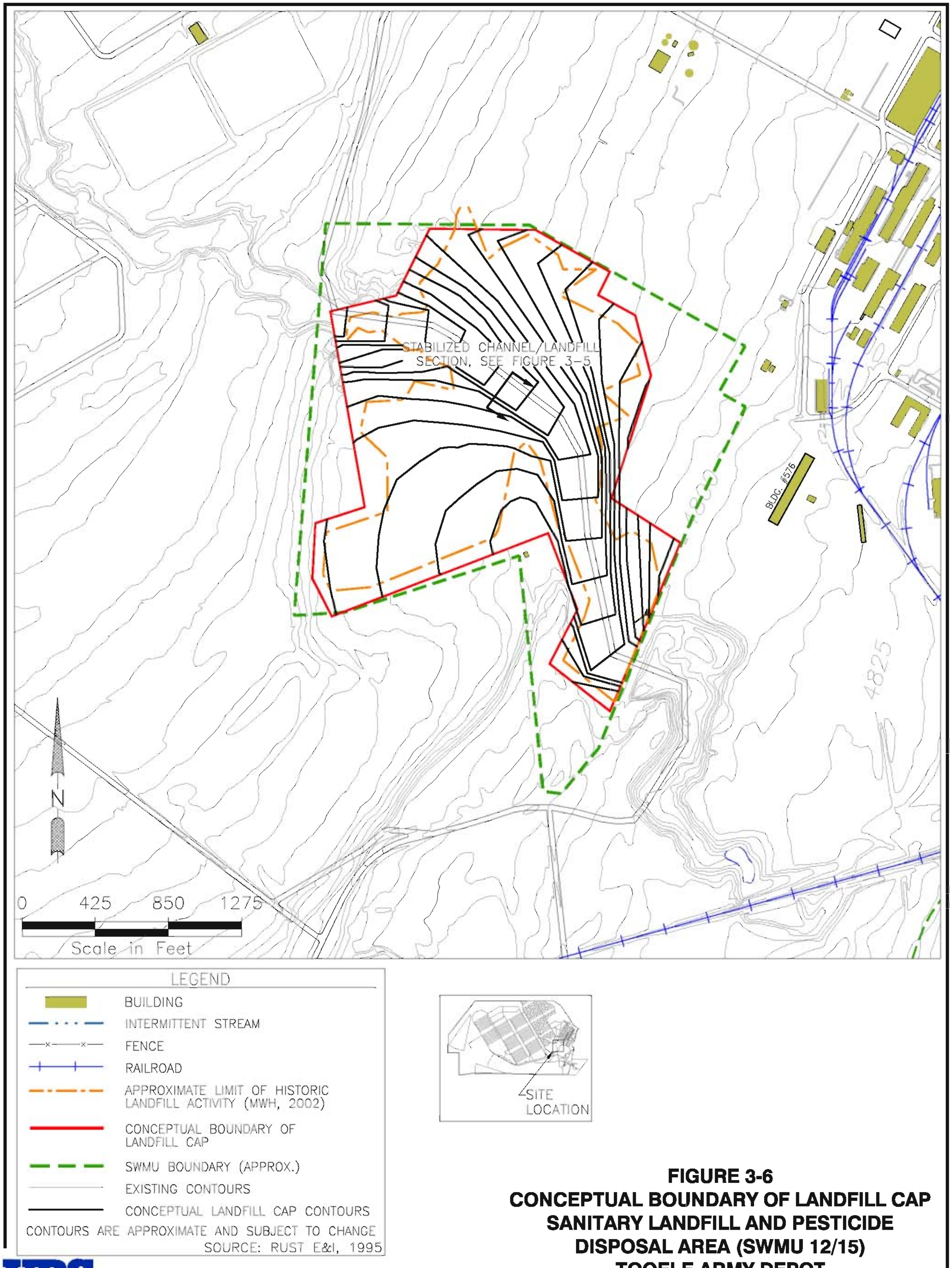

FIGURE 3-6
CONCEPTUAL BOUNDARY OF LANDFILL CAP
SANITARY LANDFILL AND PESTICIDE DISPOSAL AREA (SWMU 12/15)
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performed. Revisions to the monitoring program and the discontinuation of the program will be decided as part of the SWMU 58 Implementation of Alternative Measures.

The final component of Alternative 1 is the application of land use restrictions to prevent groundwater use and future residential use of the site. These restrictions will also not allow construction activities (other than cover maintenance) without a construction health and safety assessment subject to UDEQ review and approval. These restrictions would be incorporated into TEAD's master land use plan. This plan also calls for inspections and monitoring to ensure the restrictions are being observed. Because U.S. Army regulations direct that all revisions to the plan be evaluated with regard to potential impacts to human health and the environment, unauthorized future use (i.e., residential or construction) of SWMU 12/15, or transfer, requires the resolution of conflicts between identified risks and hazards and proposed changes in land use at the site.

The real property planning board has authority over land use at the Depot, and is responsible for developing, enforcing, and modifying the installation's master land use plan. The authority of the board is derived from the responsible major Army command (i.e., OSC), which has specific oversight functions. These responsibilities include approving the installation's master land use plan and any proposed changes. Appendix C of the CMS Work Plan (Dames & Moore, 2000) presents a more detailed description of land use restrictions.

Appendix A (Section A.1) presents the detailed design and cost assumptions for this alternative.

Alternative 1 – Multilayer cap, groundwater monitoring, and land use restrictions – is evaluated as follows:

- <u>Technical criteria</u>

  – <u>Performance</u> – The multilayer cover system provides a stable cover over all areas of buried debris. The cover controls wind dispersion of buried waste and provides long-term minimization of migration of liquids through the closed landfill. The multilayer cover has a permeability less than or equal to the permeability of any bottom liner system or natural subsoils. This alternative also incorporates a stormwater management system to collect and control landfill runoff. Provisions for inspection and maintenance of the cover system are included in this alternative. Groundwater monitoring will continue to be performed.

    The application of land use restrictions and construction of the landfill cap comply with UAC R315-101-3, the "Principle of Non-Degradation," by preventing the potential migration of buried waste and constituents to other environmental media. Although the buried waste and constituents above the quantitative CAOs are left in place, Alternative 1 achieves the qualitative CAOs by preventing human exposure to buried waste and contaminated soils. This alternative is applicable to both site and contaminant characteristics; as long as the inspection and maintenance activities are properly completed, it meets the identified CAOs with no decrease in effectiveness over time.

– Reliability – Land use restrictions are effective over the long term and have been implemented at many sites with positive results. Inspection and maintenance are required to ensure the long-term effectiveness of the multilayer cover system. The physical properties of GCLs are subject to extensive quality assurance/quality control at the manufacturing location, which results in a uniform and highly dependable material. GCLs are typically easy to install. However the arid climate at TEAD could potentially affect the long term performance of the GCL. Moreover, the permeability of GCLs can be adversely impacted by out of plane deformations caused by moderate differential settlement in the cover system. Nevertheless, GCLs have been used in many landfill cover systems with positive results and the long-term reliability of the GCL is not likely to decrease with time.

  This alternative would require re-establishing vegetation over the capped area. The existing vegetative cover has developed over the course of years and includes brushes and grasses with extensive root systems. Under this alternative, vegetation with root systems deeper than 30 inches would rupture the geomembrane and cannot be allowed. Providing a new vegetative cover of SWMU 12/15 will likely require years of extensive maintenance. Soil and erosion controls may be necessary for several years or longer.

– Implementability – Engineering design capabilities and construction labor and equipment for the cover system are readily available. However, the very large amount of excavation and earthmoving required and likely disturbance of buried debris may impede implementation. Due to the hilly terrain of the landfill, extensive regrading of the existing surface is necessary to provide the relatively uniform, shallow slopes required by the cover system presented in this alternative. The largest potential area of excavation is the hill in the central portion of the landfill between the inactive sewage evaporation basin to the southeast and the arroyo to the north. The depth of excavation is this area would be an average of approximately 10 feet. The presence of buried debris within excavated areas will significantly increase the cost of excavation and require additional safety protocols. The presence of buried metal debris will significantly increase the time and cost to perform UXO screening due to false positives. Therefore, large amounts of excavation are impractical in areas of buried debris. The final grading plan must be preceded by an investigation to determine whether the areas slated for excavation have buried debris. The inability to excavate these areas would result in significantly more soil fill required to provide the required landfill cover surface grade.

Because the specified future land use for SWMU 12/15 is military, continuing land use restrictions at this site should not be difficult. Approximately 5 years is required to complete design and site construction activities and to meet the CAOs. Existing wells will be used for groundwater monitoring.

– Safety – Because the activities associated with landfill capping are conducted on post, this alternative poses no health risks to off-post residential communities. Onsite workers may be exposed to waste-contaminated soil during excavation and grading activities or to contaminated groundwater during sampling events. However, these risks are short term; the physical hazards associated with heavy construction and excavation activities (e.g., noise, heavy equipment traffic, slope stability, buried debris, and potential UXO) require the use of PPE, UXO protective measures, and compliance with applicable Army and Occupational Safety and Health Administration (OSHA) regulations. Groundwater sampling also requires the proper level of personal protective equipment (PPE).

- Human health assessment – Land use restrictions and installing a cover system over areas of historic landfill activity protects human health by preventing both short-and long-term exposure to buried waste and contaminants in soil and groundwater. The risk assessment identified acceptable cancer risks and HIs for the current and future anticipated Depot worker land use scenario. Surface soil COCs for Depot workers occur at six locations within the landfill. However, because a concentration equal to the CAO is equivalent to a cancer risk of 1×10^{-6}, the COCs do not result in unacceptable risk levels which are set at 1×10^{-5} for Depot workers. This conclusion is confirmed by results of the Depot worker RA. For construction workers, the cancer risks were acceptable but the HI was above 1.0. The land use restrictions will not allow construction activities (other than cover maintenance) unless potential construction worker risks are investigated and addressed.

  Some degree of long-term liability is associated with the covered contaminated soil left on site. The residual risk remaining on site for soil results from soil contamination below the capped landfill, thus reducing exposure potential. Restricting future development of SWMU 12/15 prevents residential exposure to soil and groundwater contaminants.

- Environmental assessment – The SWERA (Rust E&I, 1997) indicated that SWMU 12/15 presents an unacceptable risk to ecological receptors at limited locations. The installation of a cover system over contaminated areas reduces this risk by preventing exposure to buried waste and contaminated soil at the site. See Appendix C.

- Administrative feasibility – This alternative complies with applicable Federal and State laws and regulations, including the requirements of UAC R315-101, by preventing exposure to buried waste and contaminated soil. Land use restrictions prevent the potential for residential exposure to contaminated soils. Because SWMU 12/15 is to remain under U.S. Army Control, land use restrictions will be administered through the installation's Real Property Planning Board.

- Cost – The estimated present worth cost of implementing this corrective measures alternative is 28,800,000. Table A-1 (Appendix A) presents the detailed cost estimate.

3.2.2 Alternative 2 – Evapotranspiration Landfill Cover, Groundwater Monitoring, and Land Use Restrictions

This alternative includes designing and constructing an ET cover at SWMU 12/15 over all areas of buried debris. It also includes groundwater monitoring and land use restrictions for SWMU 12/15.

An ET cover is proposed to minimize infiltration and the burrowing of animals. Figure 3-7 depicts the proposed final cover system under this alternative. Appendix A presents the cost estimate and Appendix B presents the conceptual design. From top to bottom, the proposed ET cover is to be composed of:

- A 6-inch protective vegetated top soil layer designed to minimize cap erosion and to promote drainage off the cap. Section B.3.4.2 of Appendix B discusses the re-establishment of vegetation. The surface shall have slopes of at least 3 percent but not more than 5 percent over most of the capped area. Surface slopes of up to 33 percent will occur for short distances on side slopes near the landfill perimeter.

- A 24-inch protective soil layer consisting of soil borrowed from on and off-site. This layer is designed to minimize erosion, accommodate shallow root penetration and freeze/thaw problems and store infiltrated water for later evaporation. Based on a frost depth of 21 to 24 inches, approximately 6 to 9 inches or more of this soil cover will be available year-round for lateral drainage of water.

- An 18-inch barrier soil layer that provides long-term minimization of water filtration into the underlying landfill. It will be comprised of compacted local borrow soils amended with bentonite or other material if necessary to achieve a permeability of at least 1×10^{-5} cm/sec after placement and compaction.

NOT TO SCALE

NOTE: FOUNDATION SOIL LAYER MAY INCLUDE EXISTING COVER LAYER.

FIGURE 3-7
EVAPOTRANSPIRATION LANDFILL COVER CROSS SECTION (TYPICAL)
SANITARY LANDFILL AND
PESTICIDE DISPOSAL AREA (SWMU 12/15)
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- A foundation soil layer which serves as the structural base for the final cover. It includes the daily and intermediate soils which cover the buried waste and any additional soil required to prepare the landfill for construction of the final cover (i.e., smoothing out high relief). Based on the topography and the thickness of buried waste at SWMU 12/15 it is estimated that approximately 600,000 yd^3 of foundation layer fill soil will be required over the limit of the landfill in order to maintain the minimum slope requirement of 3 percent for the cap and to reduce the potential for damage from settlement and subsidence. Approximately one-third of the volume will be excavated from high points within the landfill and moved to low points. The existing vegetation will be stripped and the ground prepared (i.e., stabilized where necessary) before constructing the foundation soil layer. It is assumed UXO screening of excavated areas will be required.

As discussed in Appendix B, the HELP model was used to evaluate infiltration rates for an ET cover. The barrier soil layer is assumed to have a permeability of 1×10^{-5} cm/sec. The compacted soil is assumed to be amended with bentonite to achieve this permeability. In addition to this barrier layer, the soil cover includes three other layers: two vertical percolation layers, and a lateral drainage layer. The mean monthly infiltration for this scenario is 0.029 inches per unit area. The percent of the total precipitation infiltrating and reaching the buried wastes is 2.36 percent.

Also included in the landfill cover is a stormwater management system to control runoff from rainfall and snowmelt. A large portion of the landfill cap run off will flow into the existing arroyo which will be stabilized to prevent infiltration of stormwater, landfill runoff to buried waste, and cap erosion. A stabilized channel of soil-cement cover will channel runoff from the cap to a stable outlet where it can evaporate or flow beyond the cap (see Figure 3-5). This channel will also serve as a structural reinforcing element for the landfill cover on the adjacent hill slopes. The channel is to provide hydraulic capacity for stormwater flow. An additional benefit will be the use of the channel for vehicle access to the interior of the landfill for inspection and maintenance.

A soil-cement channel was selected over the other potential options (asphalt channel and extension of the cap to cover the channel) on the basis of durability, reliability, performance, implementability, and cost. However, the application of a low permeability, low maintenance modified asphalt cover should be investigated as an alternative during the design phase.

The historical extent of the landfill is approximately 70 acres. This entire area will be capped with all of the components discussed above (see Figure 3-6). To be conservative and account for the irregular shape of the landfill, 90 acres is assumed. An additional 30 acres is estimated to be necessary around the cap perimeter to provide a uniform but not excessively steep surface grade from the cap to the surrounding existing ground surface. This additional cover area is assumed not to require the barrier soil layer.

It is assumed that sections of the existing landfill can be excavated to establish acceptable surface slopes and to provide a source of foundation soil for fill areas. This assumption is necessary because of the high topographic relief in sections of the landfill. If these sections cannot be excavated due to buried waste, UXO, or other problems, then a potentially large volume of additional fill material will be needed. Potential on-post sources of fill exist, although the adequacy of the material must be tested prior to design. It is assumed that a leachate collection system will not be required as part of the cover design. It is assumed that inspection and maintenance of the cover and surface water system will occur for 30 years. A final assumption is that only moderate surface water flow occurs in the arroyo.

Alternative 2 also includes groundwater monitoring and land use restrictions, as described in Section 3.2.1.

Appendix A (Section A.1) outlines the design and cost assumptions for this alternative.

Alternative 2 – ET cover, groundwater monitoring, and land use restrictions – is evaluated as follows:

- Technical criteria

  - Performance – The soil cover system provides a stable cover over all areas of buried debris. This cover controls wind dispersion of buried waste and provides long-term minimization of migration of liquids through the closed landfill. The ET cover has a permeability less than or equal to the permeability of any bottom liner system or natural subsoils. This alternative also incorporates a stormwater management system to collect and control landfill runoff. Provisions for inspection and maintenance of the cover system are included in this alternative. Groundwater monitoring will continue to be performed.

    The application of land use restrictions and construction of the landfill cap comply with UAC R315-101-3, the "Principle of Non-Degradation," by preventing the potential migration of buried waste and constituents to other environmental media. Although the buried waste and constituents above the quantitative CAOs are left in place, Alternative 2 achieves the qualitative CAOs by preventing human exposure to buried waste and contaminated soils. This alternative is applicable to both site and contaminant characteristics; as long as the inspection and maintenance activities are properly completed, it meets the identified CAOs with no decrease in effectiveness over time.

  - Reliability – The landfill cap in conjunction with land use restrictions is expected to be effective over the long term. Inspection and maintenance are required to ensure the long-term effectiveness of the soil cover system.

This alternative would require re-establishing vegetation over the covered area. The existing vegetative cover has developed over the course of years and includes brushes and grasses with extensive root systems. Under this alternative, vegetation with root systems deeper than 30 inches may cause cracks to form in the barrier soil layer. Providing a new vegetative cover at SWMU 12/15 will likely require years of extensive maintenance. Soil and erosion controls may be necessary for several years or longer, as vegetation rebounds.

– Implementability – Engineering design capabilities and construction labor, equipment and materials for the ET cover system are readily available. However, the very large amount of excavation and earthmoving required and likely disturbance of buried debris may impede implementation. Due to the hilly terrain of the landfill, extensive regrading of the existing surface is necessary to provide the relatively uniform, shallow slopes required by the cover system presented in this alternative. The largest potential area of excavation is the hill in the central portion of the landfill between the inactive sewage evaporation basin to the southeast and the arroyo to the north. The depth of excavation is this area would be an average of approximately 10 feet. The presence of buried debris within excavated areas will significantly increase the cost of excavation and require additional safety protocols. The presence of buried metal debris will significantly increase the time and cost to perform UXO screening due to false positives. Therefore, large amounts of excavation are impractical in areas of buried debris. The final grading plan must be preceded by an investigation to determine whether the areas slated for excavation have buried debris. The inability to excavate these areas would result in significantly more soil fill required to provide the required landfill cover surface grade.

  Because the specified future land use for SWMU 12/15 is continued military use, continuing land use restricting at this site should be easy. Approximately 5 years is required to complete design and site construction activities and to achieve qualitative CAOs. Existing wells will be used for groundwater monitoring.

– Safety – Because the activities associated with landfill capping are conducted on post, this alternative poses no health risks to off-post residential communities. Onsite workers may be exposed to waste-contaminated soil during excavation or grading activities. However, these risks are short term; the physical hazards associated with heavy construction and excavation activities (e.g., noise, heavy equipment traffic, slope stability, buried debris, and potential UXO) require the use of PPE, UXO protective measures, and compliance with applicable Army and OSHA regulations. Groundwater sampling also requires the proper use of PPE.

- Human health assessment – Land use restrictions and installing a cover system over areas of historic landfill activity protects human health by preventing both short-and long-term exposure to buried waste and contaminants in soil and groundwater. The risk assessment identified acceptable cancer risks and HI for the current and future anticipated Depot worker land use scenario. Surface soil COCs for Depot workers occur at six locations within the landfill. However, because a concentration equal to the CAO is equivalent to a cancer risk of 1×10^{-6}, the COCs do not result in unacceptable risk levels which are set at 1×10^{-5} for Depot workers. This conclusion is confirmed by results of the Depot worker RA. For construction workers, the cancer risks were acceptable but the HI was above 1.0. The land use restrictions will not allow construction activities (other than cover maintenance) unless potential construction worker risks are investigated and addressed.

  Some degree of long-term liability is associated with the covered contaminated soil left on site. The residual risk remaining on site for soil results from soil contamination below the covered landfill, thus reducing the potential for exposure. Restricting future development of SWMU 12/15 prevents residential and construction worker exposure to soil and groundwater contaminants.

- Environmental assessment – The SWERA (Rust E&I, 1997) indicated that SWMU 12/15 presents an unacceptable risk to ecological receptors at limited locations. The installation of a cover system over contaminated areas reduces this risk by preventing exposure to buried waste and contaminated soil at the site. See Appendix C.

- Administrative feasibility – This alternative complies with applicable Federal and State laws and regulations, including the requirements of UAC R315-101, by preventing exposure to buried waste and contaminated soil. Land use restrictions prevent the potential for residential exposure to contaminated soil. Because SWMU 12/15 is to remain under U.S. Army control, land use restrictions will be administered through the installation's Real Property Planning Board.

- Cost – The estimated present worth cost of implementing this corrective measures alternative is $21,200,000. Table A-2 (see Appendix A) presents the detailed cost estimate.

3.2.3 Alternative 3 – Improve Existing Soil and Vegetative Cover, Groundwater Monitoring, and Land Use Restrictions

This alterative involves improving the existing cover to provide a stable soil cover over all areas of buried debris. The cover shall be maintained to prevent exposure of buried waste due to wind or erosion. This alternative also includes groundwater monitoring and land use restrictions for SWMU 12/15.

Currently the landfill is covered by a layer of soil with vegetation. Section B.3 of Appendix B presents a preliminary evaluation of the existing landfill cover. The cover will be improved by evaluating the soil and vegetative cover and upgrading where necessary to provide a stable cover over all areas of buried material.

During the design phase for the corrective measure, an evaluation of the condition of the existing soil cover will be performed. Objectives of the evaluation include identifying all areas of exposed surface debris, the types and abundance of vegetation, and the potential for soil erosion due to precipitation and stormwater runoff. A hydrology evaluation will identify patterns of precipitation runoff. Soil erosion is typically due to high wind, stormwater runoff velocities and flow rates, poor vegetation, steep or unstable bank slopes, and poor soil bearing capacity. Below are preliminary recommendations for upgrading the soil cover. The detailed evaluation described above will be necessary to verify and substantiate the assumptions in this report and develop an engineering design. Section B.5.3 presents these preliminary recommendations in more detail.

As discussed in Appendix B, Section B.5.3.1, a preliminary elevation of the landfill topography suggests that there are no major areas of potential exposure of buried wastes due to erosion. Most of the gently sloped areas are covered with vegetation. Some of the southern slopes of the arroyo are steep but have a very small upgradient drainage area. The soil on these slopes is protected by a cover of cobbles and shrubs. Therefore, the need to perform major changes to the current topography is not deemed necessary. However, periodic site inspections should be conducted to observe for soil erosion, especially in areas identified as having the potential for exposed debris due to erosion.

As discussed in Appendix B, the HELP model was used to evaluate infiltration rates for the existing soil cover assuming that two feet of native soil with a permeability of $2x10^{-3}$ cm/sec have been placed over the existing landfill. The mean monthly infiltration for this scenario is 0.061 inches per unit area. The percent of the total precipitation infiltrating and reaching the buried wastes is 4.92 percent.

The potential for water ponding in low points of the landfill is of concern, especially in areas of subsurface soil contamination. As discussed in Section B.5.3.2, two slight depressions in a narrow segment of the western arroyo (Figure 3-8) are possible locations of significant water ponding due to the relatively large amount of upstream drainage area. It is recommended that these areas be regraded to promote better drainage via the arroyo. The amount of soil fill and excavation necessary to regrade this area and prevent ponding is approximately 1,000 cubic yards and 800 cubic yards, respectively.

It is also recommend that the drainage area in the southeast leg of the landfill (see Figure 3-8 be regraded to prevent ponding due to its relatively large drainage area (10 acres), steep slopes, and the potential presence of buried wastes. The goal of regrading would be to allow precipitation runoff from this area to drain into the arroyo. Regrading would consist of adding soil to the deepest part of the depression and excavating portions of the surrounding hillside to provide an outlet for the runoff to reach the arroyo. The amount of soil fill and soil excavation necessary is approximately 10,300 cubic yards and 1,000 cubic yards, respectively. It is assumed UXO screening will be required for excavated areas.

Under this alternative, exposed surface debris will be covered with soil and revegetated. To minimize the amount of new soil cover and vegetation necessary, when possible, surface debris will be collected, centralized, and covered. One potential area where debris could be centralized and covered is the depression in the southeast leg of the landfill where regrading is recommended. The soil cover will consist of 2 feet of native soil, 3 inches of topsoil and vegetation. The cover is assumed to mimic the existing site topography with the exception of steeper slopes along cover perimeters.

Vegetation is a major component of soil stability. Areas with poor vegetative cover may need seeding to provide increased vegetation and soil stabilization. It is estimated that 30 acres will require seeding. This includes areas to receive additional soil cover as described above. The current condition of the vegetation at the landfill is discussed in Appendix B, Section B.3.4. This section also discusses the re-establishment of vegetation. The revegetation activities will promote a diverse plant community by planting native perennial species, such as crested wheatgrass.

This alternative also includes cover inspections and soil cover maintenance to ensure buried debris does not become exposed. A landfill cover maintenance plan will be developed to provide guidance for inspecting and maintaining the soil cover. As part of the maintenance plan, a vegetation plan will be developed and implemented to ensure a strong vegetative layer throughout the landfill cover. Attachment 1 of the TEAD Post-Closure Permit is the *Post-Closure Monitoring, Maintenance, and Inspection of the Industrial Waste Lagoon (IWL), Associated Wastewater Collection Ditches, and Groundwater Treatment System*. This attachment addresses the inspection and maintenance activities for the cover at the IWL and provides a useful example of requirements to be included in the maintenance plan for the soil cover at SWMU 12/15.

Alternative 3 also includes groundwater monitoring and land use restrictions, as described in Section 3.2.1.

Appendix A (Section A.1) outlines the design and cost assumptions for this alternative.

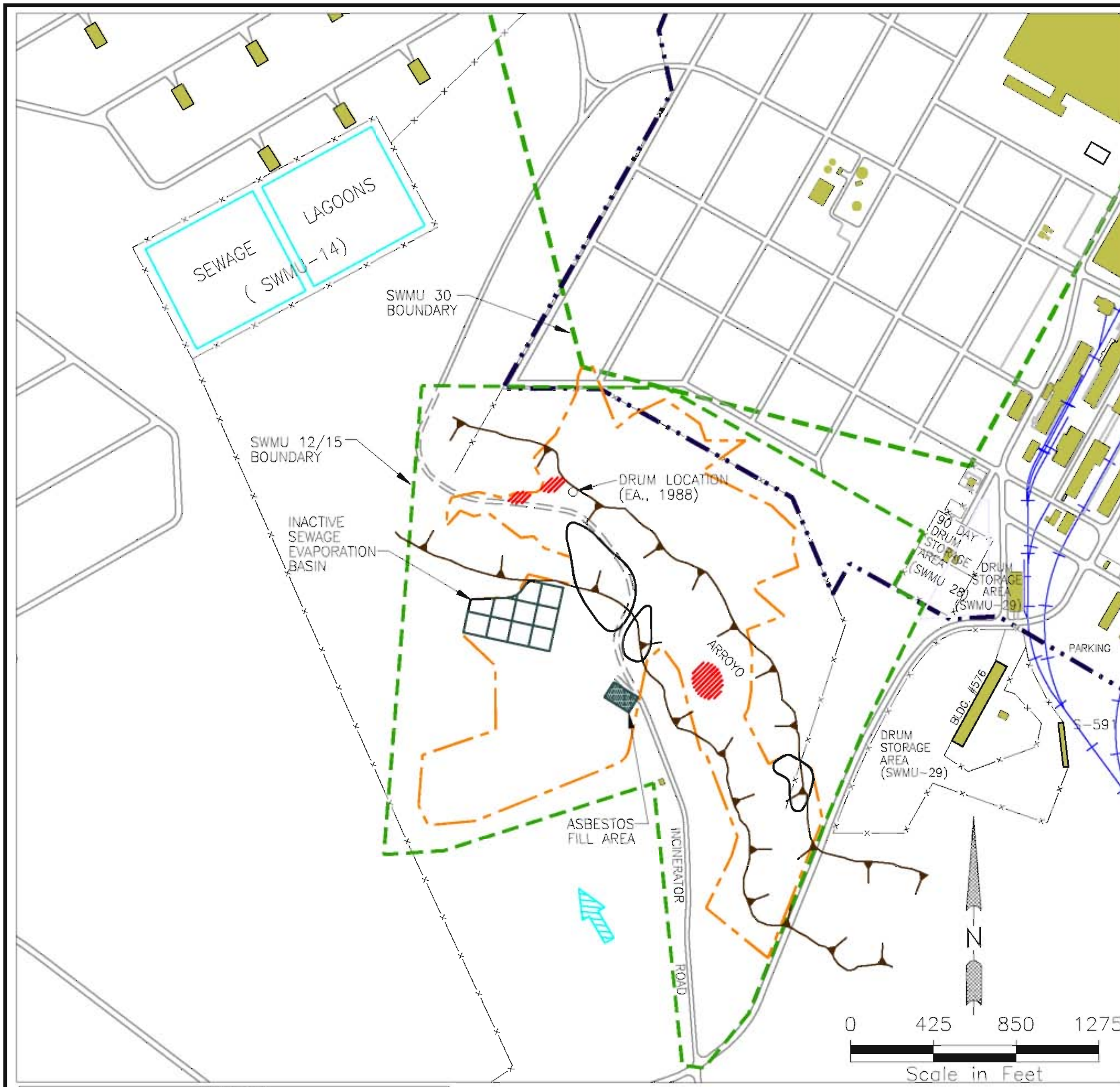

FIGURE 3-8
EVALUATION OF EXISTING SOIL AND VEGETATIVE COVER
SANITARY LANDFILL AND PESTICIDE DISPOSAL AREA (SWMU 12/15)
TOOELE ARMY DEPOT

URS

Alternative 3 – Improve existing soil and vegetative cover, groundwater monitoring, and land use restrictions – is evaluated as follows:

- Technical criteria

  – Performance – The soil cover system provides a stable cover over all areas of buried debris. This cover controls wind dispersion of exposed waste and provides long-term minimization of migration of liquids through the closed landfill. Provisions for inspection and maintenance of the cover system are included in this alternative. Groundwater monitoring will continue to be performed.

    The application of land use restrictions and construction of the landfill cap comply with UAC R315-101-3, the "Principle of Non-Degradation," by preventing the potential migration of buried waste and constituents to other environmental media. Although the buried waste and constituents above the quantitative CAOs are left in place, Alternative 3 achieves the qualitative CAOs by preventing human exposure to buried waste and contaminated soils. This alternative is applicable to both site and contaminant characteristics; as long as the inspection and maintenance activities are properly completed, it meets the identified CAOs with no decrease in effectiveness over time.

  – Reliability – The landfill cover in conjunction with land use restrictions is expected to be effective over the long term. Routine inspection and maintenance are required to ensure the long-term effectiveness of the cover and to avoid exposure of debris due to wind and water erosion.

  – Implementability – Engineering design capabilities, and construction labor, equipment and materials for improving the existing cover system are readily available. A relatively small amount of excavation is proposed under this alternative. Excavation issues include disturbance of buried debris and UXO screening. Because the specified future land use for SWMU 12/15 is continued military use, continuing land use restrictions at this site should be easy. Approximately 1 year is required to complete design and site construction activities and to achieve qualitative CAOs. Existing wells will be used for groundwater monitoring.

  – Safety – Because the activities associated with the landfill cover are conducted on post, this alternative poses no health risks to off-post residential communities. Onsite workers may be exposed to waste-contaminated soil during excavation or grading activities. However, these risks are short term; the physical hazards associated with heavy construction and excavation activities (e.g., noise, heavy equipment traffic, slope stability, surface debris, and potential UXO) require the use of PPE, UXO protective measures, and compliance with applicable Army and OSHA regulations. Groundwater sampling also requires the proper use of PPE.

- Human health assessment – Land use restrictions and improving and maintaining a cover system over areas of historic landfill activity protects human health by preventing both short- and long-term exposure to buried waste and contaminants in soil and groundwater. The risk assessment identified acceptable cancer risks and HIs for the current and future anticipated Depot worker land use scenario. Surface soil COCs for Depot workers occur at six locations within the landfill. However, because a concentration equal to the CAO is equivalent to a cancer risk of 1×10^{-6}, the COCs do not result in unacceptable risk levels which are set at 1×10^{-5} for Depot workers. This conclusion is confirmed by results of the Depot worker RA. For construction workers, the cancer risks were acceptable but the HI was above 1.0. The land use restrictions will not allow construction activities (other than cover maintenance) unless potential construction worker risks are investigated and addressed.

  Some degree of long-term liability is associated with the contaminated soil covered but still onsite. The residual risk remaining onsite for soil results from soil contamination below the covered landfill. Restricting future development of the site prevents residential and construction worker exposure to soil and groundwater contaminants.

- Environmental assessment – The SWERA (Rust E&I, 1997) indicated that SWMU 12/15 presents an unacceptable risk to ecological receptors in limited areas. Improvements to the cover system reduces this risk by preventing exposure to buried waste and contaminated soil at the site.

- Administrative feasibility – This alternative complies with applicable Federal and State laws and regulations, including the requirements of UAC R315-101 by preventing exposure to buried waste and contaminated soil. Land use restrictions prevent the potential for residential exposure to contaminated soil. Because SWMU 12/15 is to remain under U.S. Army control, land use restrictions will be administered through the installation's Real Property Planning Board.

- Cost – The estimated present worth cost of implementing this corrective measures alternative is $3,000,000. Table A-3 (Appendix A) presents the detailed cost estimate.

3.3 COMPARATIVE ANALYSIS OF CORRECTIVE MEASURES ALTERNATIVES

Table 3-2 and the text below summarize the comparative analysis of the three corrective measures alternatives developed for the Sanitary Landfill/Pesticide Disposal Area (SWMU 12/15).

- Technical criteria

  – Performance – Each alternative eliminates the risk of exposure to contaminants in soil and so each alternative receives a high rating for this criterion. In addition, each alternative meets the qualitative CAOs as long as inspection and maintenance activities are properly completed.

  – Reliability – Each alternative has been shown to be effective at other sites but may not achieve the CAOs over the long term if cover inspections and maintenance are not performed. Each of the three alternatives is rated moderate for reliability. Re-establishing vegetation will be difficult for Alternatives 1 and 2.

  – Implementability – Alternatives 1 and 2 each involve a large amount of excavation and earthmoving and the likely disturbance of buried debris. They are both rated moderate. UXO screening will likely be required for excavation within the landfill. The presence of buried debris within excavated areas will significantly increase the cost of excavation and require additional safety protocols. The presence of buried metal debris will significantly increase the time and cost to perform UXO screening due to false positives. The inability to excavate these areas would result in significantly more soil fill required to provide the required landfill cover surface grade. Alternative 3 is rated high because it requires significantly less excavation and earthmoving activities.

  – Safety – Alternatives 1 and 2 are rated moderate because they require extensive excavation and earthmoving activities. Atypical excavation safety issues include buried debris and potential UXO. Alternative 3 is rated high because it involves significantly less excavation and earthmoving activities. Each of the three alternatives requires appropriate equipment during installation, inspection and maintenance activities.

- Human health assessment – Each of the alternatives is equally protective of Depot workers, construction workers, and residents; and is rated high.

TABLE 3-2

Comparative Analysis of Corrective Measures Alternatives
Sanitary Landfill/Pesticide Disposal Area (SWMU 12/15) (a)

Corrective Measures Alternative	Technical Evaluation				Human Health Assessment	Environmental Assessment	Administrative Feasibility	Cost
	Performance	Reliability	Implementability	Safety				
1. Multi-layer landfill cap, groundwater monitoring, and land use restrictions	High	Moderate	Moderate	Moderate	High	High	High	$28,800,000
2. ET landfill cover, groundwater monitoring, and land use restrictions	High	Moderate	Moderate	Moderate	High	High	High	$21,200,000
3. Improve existing soil and vegetative cover, groundwater monitoring, and land use restrictions	High	Moderate	High	High	High	Moderate	High	$3,000,000

(a) Rankings of high, moderate, or low indicate the effectiveness of each alternative in meeting the evaluation criteria, relative to other alternatives.

- Environmental assessment – Alternatives 1 and 2 will significantly reduce ecological risks and are rated high. Alternative 3 will provide some reduction of exposure to contamination. However, because these risks are limited in area, Alternative 3 is rated moderate.

- Administrative feasibility – Each alternative is rated high for administrative feasibility because they comply with all applicable Federal and State regulations.

- Cost – The estimated present worth costs are $28,800,000 (Alternative 1), $21,200,000 (Alternative 2), and $3,000,000 (Alternative 3), respectively.

All three alternative cost estimates are sensitive to a number of parameters. The table below presents a qualitative assessment of the relative cost sensitivity of the three alternatives to different parameters.

Parameter	Alternative 1	Alternative 2	Alternative 3
Extent of surface debris present	Low	Low	High
Availability of on-post soil fill	High	High	Low
Regrading (i.e., excavation) of site soil	High	High	Low
Existing soil cover thickness	Low	Low	High
Revegetation of disturbed soil	High	High	Low
UXO present in subsurface soil	High	High	Low

3.4 RECOMMENDED CORRECTIVE MEASURES ALTERNATIVE

Based on the comparative analysis presented in Section 3.3, Alternative 3 – Improve existing soil and vegetative cover, groundwater monitoring, and land use restrictions – is recommended as the preferred alternative for SWMU 12/15 because:

- It meets the quantitative and qualitative CAOs, including protection of human health and the environment, and complies with UAC R315-101-3, the "Principle of Non-Degradation."

- It has been demonstrated at other sites.

- It is reliable.

- It can be safely implemented.

- It requires relatively little waste handling.

- It is cost effective.

- It does not preclude possible future engineering activities to address groundwater contamination, because such activities are not likely to adversely affect the integrity of the soil and vegetative cover.

4.0 SUMMARY OF THE RECOMMENDED CORRECTIVE MEASURES ALTERNATIVE

Based on the evaluation of corrective measures alternatives, the recommended alternative for SWMU 12/15 is Alternative 3. The recommendation is based on the evaluation criteria considered in the detailed analysis, as reported in Section 3.0. Table 4-1 summarizes the evaluations conducted for SWMU 12/15.

The recommended corrective measures alternative for the site is to improve the existing soil and vegetative cover, continue groundwater monitoring, and implement land use restrictions. This alternative effectively meets the objectives of the CMS, takes advantage of the existing site vegetation, and is extremely cost effective. It is critical that the site have a routine cover inspection and maintenance program to avoid exposure of debris due to wind and water erosion. The implementation of this alternative will not preclude the possibility of future corrective measures for the site groundwater.

TABLE 4-1

Summary of Comparative Analysis of Corrective Measures Alternatives
Sanitary Landfill/Pesticide Disposal Area (SWMU 12/15)
Tooele Army Depot

SWMU	Technical Evaluation				Human Health Assessment	Environmental Assessment	Administrative Feasibility	Cost ($)
Corrective Measures Alternative (a)	**Performance**	**Reliability**	**Implementability**	**Safety**				
Sanitary Landfill/Pesticide Disposal Area (SWMU 12/15)								
Alternative 1: Multi-layer landfill cap, groundwater monitoring, and land use restrictions	Meets all identified CAOs if landfill cover is properly maintained	Proven effective at other sites; long-term landfill cover O&M and groundwater monitoring required	Extensive excavation, UXO screening, and earthmoving required	Short-term risk to onsite workers minimized by engineering and safety controls	Protective of human health	Prevents exposure of ecological receptors to contaminated soil	Meets requirements of UAC R315-101	28,800,000
Alternative 2: ET landfill cover, groundwater monitoring, and land use restrictions	Meets all identified CAOs if landfill cover is properly maintained	Proven effective at other sites; long-term landfill cover O&M and groundwater monitoring required	Extensive excavation, UXO screening, and earthmoving required	Short-term risk to onsite workers minimized by engineering and safety controls	Protective of human health	Prevents exposure of ecological receptors to contaminated soil	Meets requirements of UAC R315-101	21,200,000
Alternative 3: Improve existing soil and vegetative cover, groundwater monitoring, and land use restrictions	Meets all identified CAOs if landfill cover is properly maintained	Proven effective at other sites; long-term landfill cover O&M and groundwater monitoring required	Easily implemented under current conditions	Short-term risk to onsite workers minimized by engineering and safety controls	Protective of human health	Partly prevents exposure of ecological receptors to contaminated soil	Meets requirements of UAC R315-101	3,000,000

(a) The recommended corrective measures alternative is shown in bold italic type.

5.0 REFERENCES

Bleak, A. T.; Frischknecht, N. C.; Plummer, A. Perry; Eckert, R. E., Jr. 1965. *Problems in artificial and natural revegetation of the arid shadscale vegetation zone of Utah and Nevada. Journal of Range Management*. 18: 59-65. [3992]

Bunting, Stephen C.; Kilgore, Bruce M.; Bushey, Charles L. 1987. Guidelines for prescribed burning sagebrush-grass rangelands in the northern Great Basin. Gen. Tech. Rep. INT-231. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 33 p. [5281]

Chambers, Jeanne C. 1989. Native species establishment on an oil drillpad site in the Uintah Mountains, Utah: effects of introduced grass density and fertilizer. Res. Pap. INT-402. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 9 p. [6885]

Dames & Moore (URS-Dames & Moore), 2001. *Final, Known Releases SWMUs, Tooele Army Depot, Tooele, Utah, Additional Field Investigation Report*, Contract No. DACA31-94-D-0060, prepared for Tooele Army Depot, Tooele, Utah, November 2001.

Dames & Moore, 2000. *Final Planning Documents, Known Releases SWMUs, Tooele Army Depot, Tooele, Utah, Volume I: Corrective Measures Study Work Plan*, Contract No. DACA31-94-D-0060, prepared for Tooele Army Depot, Tooele, Utah, February 2000.

Dames & Moore, 2000a. *Draft Known Releases SWMUs, Tooele Army Depot, Tooele, Utah, Corrective Measures Study Report*, Contract No., DACA31-94-D-0060, prepared for Tooele Army Depot, Tooele, Utah, February 2000.

Engineering Science and Technology, Inc. (EA), 1988. *Tooele Army Depot Preliminary Assessment/Site Investigation Final Report*, prepared for U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Maryland.

ITSI, 2003. *Final Work Plan, Revision #2, Interim Removal Action*, Sanitary Landfill, SWMU 12/15, Tooele Army Depot, Utah, January 2003.

Kleinfelder, 2002. *Semi-Annual Groundwater Quality Report and Voluntary SWMU Sampling, Spring 2002, Tooele Army Depot, Tooele, Utah*, prepared for U.S. Army Corps of Engineers, Sacramento District, October 2002.

Kleinfelder, 1999. *Groundwater Monitoring Report, Fall 1998, Tooele Army Depot (TEAD), Tooele, Utah*, prepared for U.S. Army Corps of Engineers, Sacramento District, July 1999.

McArthur, E. Durant; Giunta, Bruce C.; Plummer, A. Perry. 1977. Shrubs for restoration of depleted range and disturbed areas. Utah Science. 35: 28-33. [25035]

MWH, 2002. *Final, Exploration Trenching Report for SWMU 12/15, Sanitary Landfill/ Pesticide Disposal Area*, prepared for Tooele Army Depot, prepared on behalf of U.S. Army Corps of Engineers, Sacramento District, January 2002.

Plummer, A. Perry; Frischknecht, Neil C. 1952. Increasing field stands of Indian ricegrass. Agronomy Journal. 44(6): 285-289. [1902]

Radkiewicz, R. J., 1995. "Memorandum on Command Policy on Establishing Remediation Goals and Objectives at U.S. Army Industrial Operations Command (IOC) Installations," U.S. Department of the Army, Headquarters, IOC, October 10, 1995.

Rust E&I, 1997. *Tooele Army Depot-North Area, Revised Final Site-Wide Ecological Risk Assessment*, prepared for U.S. Army Environmental Center, Aberdeen Proving Ground, Maryland.

Rust E&I, 1995. *Revised Final Phase II RCRA Facility Investigation Report for Known Releases SWMUs, Tooele Army Depot-North Area*, prepared for U.S. Army Environmental Center, Aberdeen Proving Ground, Maryland.

Sperber, Marc N., 1996. *RCRA Corrective Action Manual*, Vol. I, Thompson Publishing Group, March 1996.

U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), 1979. *Installation Assessment of Tooele Army Depot:* Report No. 141, USATHAMA, Aberdeen Proving Ground, MD.

URS, 2002. *Final, Remedial Action Work Plan, Small Arms Firing Range, SWMU 8, Tooele Army Depot, Tooele, Utah*, prepared for U.S. Army Corps of Engineers, Sacramento District, June 2002.

USDA, 2000. *Soil Survey of Tooele Area, Utah*, U.S. Department of Agriculture, Natural Resources Conservation Service, issued 2000.

USEPA, 1991. *Risk Assessment Guidance for Superfund – Volume I, Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals (Interim)*, PB92-963333, Office of Emergency and Remedial Response, Washington, D.C.

Vallentine, John F. 1971. Range development and improvements. Provo, UT: Brigham Young University Press. 516 p. [2414]

APPENDIX A

Design and Cost Assumptions

APPENDIX A

Design and Cost Assumptions

The cost estimates made for this CMS are anticipated to provide an accuracy of +50 to -30 percent based on available data from previous documents related to the Known Releases SWMUs and engineering judgment.

A.1 COST ESTIMATES FOR SWMU 12/15

This appendix presents cost estimates for the corrective measures alternatives evaluation for SWMU 12/15 in this CMS Report. Section A.1.2 presents detailed cost estimates for the three corrective measures alternatives identified at SWMU 12/15.

A.1.1 DESIGN AND COST ASSUMPTIONS

Section A.1.1.1 presents the assumptions for both the multi-layer cap and the evapotranspiration (ET) covers. Section A.1.1.2 presents the assumptions for improving the existing soil cover. Section A.1.1.3 provides the assumptions for groundwater monitoring. Land use restrictions are addressed in Section A.1.1.4.

A.1.1.1 Multi-Layer and ET Landfill Covers

This section presents the design and cost assumptions for Alternative 1 – Multi-layer landfill cap, and Alternative 2 – ET landfill cover. These alternatives share many construction component costs which are summarized in this section.

Appendix B presents the conceptual design for both types of engineered landfill covers. The conceptual design discusses the components of the landfill covers in detail. The landfill cover components are presented below with cost assumptions provided. Tables A-1 and A-2 provide the detailed cost estimates for the landfill cover alternatives. Attachment 1 presents the estimated quantities of materials required to construct the landfill covers. Attachment 2 presents detailed unit cost calculations used in developing the cost estimates. Because of the size of the landfill, many of the unit costs referenced from general cost estimating sources (i.e., RS Means) will need to be verified with site-specific cost estimates and local vendor quotes. Most of the component costs are the same for both landfill types and are only listed once below and in Attachment 2.

The conceptual design and estimated costs for the landfill cap alternatives are based on several major assumptions that require further investigation before detailed design work and proposal level cost estimating can be performed. It is assumed that sections of the existing landfill may be excavated to establish acceptable surface slopes and to provide a source of foundation soil for fill areas. This assumption is necessary because of the high topographic relief in sections of the landfill. If these sections cannot be excavated due to buried waste, UXO, or other problems, then a potentially large volume of additional fill material will be needed. See implementability discussion in Sections of 3.2.1 and 3.2.2. For the purposes of this cost estimate, it is assumed that areas slated for excavation have minor amounts of buried debris, no UXO, and can be excavated without significant UXO screening. An on-post source of fill is slated for use, although the adequacy of the material must be tested prior to design. A geotechnical survey is necessary before a grading plan can be developed. For this report, it is assumed that the required quantity of cut/fill soil for the foundation layer can be estimated by multiplying the area of the cover by 4 feet. This estimate is based on limited site observations and information, and a grading plan would be needed to more accurately determine the cut/fill soil quantities. It is assumed that a leachate collection system will not be required as part of the cover design. A final assumption is that only moderate surface water flow occurs in the arroyo.

Items included in the cost estimates for Alternatives 1 and 2 and their related assumptions are listed below:

Pre-Design Investigation

- Includes costs for geotechnical investigation of the existing landfill soil conditions and tests required to determine suitability of on-post fill. Also includes cost for soil gas survey.

Surveying

- Includes costs for topographic control survey and grading control during construction of the landfill cover and the as-built survey of the completed cap.

Site Preparation

- Stormwater management and erosion and sedimentation controls including stormwater management basins will be constructed before earthmoving activities begin.

- Well abandonment of seven on-site wells not designated for continued monitoring.

- UXO Screening: Costs are included for UXO screening of areas to be excavated within the landfill. The need for UXO screening will be evaluated during the design phase. It is assumed that extensive UXO screening is not required. UXO clearance, removal, and detonation is assumed to be performed by the Army and those costs are not included.

Site Work

- Clearing: Unstable surface soil and vegetation will be stripped and stockpiled and if suitable will be reused for the protective vegetative cover layer.

- Foundation soil layer: It is estimated that approximately 0.6 million cubic yards of soil will be required to provide a foundation layer that meets slope requirements and provides an acceptable surface for the barrier layers. The thickness of the foundation layer will vary greatly due to the existing uneven topography of the landfill. Under this cost estimate it is assumed that approximately 200,000 cubic yards of on-site soil can be excavated and used as fill where needed. Another 400,000 cubic yards of off-site fill will be required to complete the foundation layer. It is assumed this fill soil will be provided from an on-base borrow pit.

- The following components are part of the multi-layer cap in Alternative 1 and shall be placed over 90 acres covering the historical landfill.

  - Gas collection layer: Geotextile wrapped geonet
  - Barrier layer: 40 mil HDPE geomembrane
  - Barrier layer: Geosynthetic clay liner
  - Soil drainage layer: Geotextile wrapped geonet

- Barrier soil layer (ET cover only): In Alternative 2, this barrier layer shall be placed over 90 acres covering the historical landfill.

- An anchor trench shall secure the 90 acre cover components.

- Protective soil layer: This layer will consist of soil at a thickness of 24 inches for both the multi-layer cap and the ET cover. It is assumed that this fill will be provided from an on-base borrow pit. This layer will cover approximately 120 acres to provide required slopes to the existing surface beyond the landfill.

- Protective vegetative cover layer: Six inches of topsoil mixed with gravel with be used for the surface layer. It is assumed that this material will be largely provided from the existing surface materials stripped and stockpiled or from an on-base borrow pit. This layer will cover approximately 120 acres.

- Vegetation: Seed and fertilizer shall cover the 120 acre surface.

Gas Management System

- Extraction wells and passive wellheads shall be installed throughout the 90 acres of the multi-layer cap. No extraction wells and a small number of passive well heads will be installed throughout the 90 acre ET cover.

Surface Water Control System

- A surface water control system will be installed including the stormwater management basins (see site work), perimeter ditches, down chutes and a stabilized channel of soil-cement cover.

Third Party Engineering

- Costs associated with providing technical engineering support during the design and construction phases of various remedial activities are assumed to be approximately $3,000 per acre of total direct costs.

UXO Work Plans

- A lump sum cost of $50,000 is included to develop required work plans for UXO screening.

Construction Contingency

- The construction contingency cost is 5 percent of the cost of the total direct costs.

Legal and Administrative

- Costs associated with any legal and administrative issues associated with implementation of the corrective action such as coordination with Federal, State, and local agencies, and landowners. Costs are assumed to be 1 percent of total direct costs.

Health and Safety Equipment and Training

- Costs associated with providing health and safety equipment (i.e., air sampling) and training for use during remediation activities are assumed to be approximately 1 percent of total direct costs.

Project Management

- Costs associated with providing construction oversite, technical direction, quality control, monthly progress reports, and invoice generation for the project are assumed to be approximately 3 percent of total direct costs.

Annual costs

- Annual operation and maintenance (O&M), and monitoring components include cover inspection, O&M of the cover, surface water management system and the gas management system. The annual O&M cost for the cover is smaller for the ET cover because rips and cracks in the ET barrier layer will be less costly to repair. Annual O&M costs for the surface water and landfill gas systems are also smaller for the ET cover because it does not have soil drainage and gas collection layers, and has no gas extraction wells. Annual costs for engineering, administration, project management, and contingency are also included.

A.1.1.2 Improve Existing Soil and Vegetative Cover

This section presents the design and cost assumptions for Alternative 3 - Improve Existing Soil and Vegetative Cover. Appendix B presents the conceptual design for this alternative. For some items, the unit costs for this alternative differ from those for Alternatives 1 and 2 due to economies of scale.

This alternative consists of improving the existing soil and vegetative cover. Currently the landfill cover consists of soil with grasses and shrubs. Appendix B presents a preliminary evaluation of the existing landfill cover and a conceptual design for improving the soil cover. Below are cost assumptions for the preliminary recommendations for upgrading the soil cover. A detailed cover evaluation will be necessary to verify and substantiate these assumptions and develop an engineering design. It is assumed the existing fence surrounding the landfill is acceptable and does not need upgrading.

Surveying

- Includes costs for topographic control survey and grading control during construction of additional soil cover and the as-built survey of the completed improved cover.

Site Preparation

- Stormwater management and erosion and sedimentation controls including silt fence and temporary drainage ditches or swales will be constructed before earthmoving activities begin.

Site Work

- UXO Screening: Costs are included for UXO screening of areas to be excavated within the landfill. The need for UXO screening will be evaluated during the design phase. UXO clearance, removal, and detonation is assumed to be performed by the Army and those costs are not included.

- Clearing: Areas where regrading or additional soil cover will occur will be cleared of vegetation.

- Access Road Improvements: The existing road running through the center of the landfill will be improved and stabilized where necessary using geotextile and gravel. A cost for a crew to install the gravel and geotextile improvements is included.

- Surface Debris Collection and Centralization: It is assumed that a four person crew will spend four weeks collecting and centralizing surface debris. The crew will use a truck and backhoe. Dense areas of surface debris will be covered in-place with a vegetative soil layer (see below). Other centralized areas of collected surface debris will also be covered with a vegetative soil layer. For cost estimating purposes it is assumed that the area of exposed surface debris (speculatively estimated as 17 acres as per Section B.3.3) can be reduced by half through collection and centralizing of rubble and debris. One potential area where debris could be centralized and covered is the depression in the southeast leg of the landfill where regrading is recommended (see Section B.5.3.2). It is assumed UXO screening is not necessary under this task.

- Soil regrading (excavation and soil fill): Two slight depressions in a narrow segment of the western arroyo are possible locations of significant water ponding due to the relatively large amount of upstream drainage area. It is recommended that these areas be regraded to promote better drainage through the arroyo. The amount of soil excavation and fill necessary to regrade this area and to prevent ponding is approximately 800 cubic yards and 1,000 cubic yards, respectively.

  It is also recommend that a drainage area in the southeast leg of the landfill (see Figure 3-8) be regraded to prevent ponding. Regrading would consist of adding soil to the deepest part of the depression and excavating portions of the surrounding hillside to the north to provide an outlet for the runoff to reach the arroyo. The amount of soil fill and soil excavation necessary is approximately 10,300 and 1,000 cubic yards, respectively.

  Soil excavation costs include labor and equipment necessary for excavation of soil for regrading purposes. UXO screening for excavated areas may also be required. Soil fill includes costs associated with transporting soil fill (excavated, from on-post, or from supplier) to site, placement of soil, and compaction, as necessary. For cost purposes, it is assumed this fill soil can be provided from an on-post borrow pit.

- Vegetative soil cover layer: The soil cover will consist of 2 feet of native soil, 3 inches of topsoil, and vegetation. The cover is assumed to take on the existing site topography with the exception of a steeper slope along the perimeter of the new covers. It is assumed that the soil and topsoil material will be provided from a combination of the existing surface materials stripped and stockpiled, from an on-post borrow pit, and from off-post suppliers. It is roughly estimated that approximately 10 acres of vegetative soil cover will be required.

- Vegetation: For cost estimating purposes it is estimated that approximately 30 acres will require seed bed preparation and seeding. A cost line item for 20 acres of 3 inches of topsoil is also included. The 20 acres includes the 10 acres of vegetative soil cover (as described above under surface debris) and the areas to be regraded. Temporary soil erosion controls and protective measures for the vegetation such as mulch and soil erosion control mats may be utilized.

    Surface Water Controls

- A surface water control system may be installed in areas where needed including grass drainage swales and soil stabilization using gravel, small rip-rap, geotextile, or other material. The quantities of gravel, geotextile, and ditch installation were roughly estimated for cost purposes only. The need for these controls will be determined during the design phase.

Engineering Design

- Includes costs associated with providing technical engineering support during the design and construction phases of the various remedial activities. This includes a detailed evaluation of the condition of the existing soil cover. Objectives of the evaluation include identifying all areas of surface debris, the types and abundance of vegetation cover, and the potential of soil erosion due to precipitation and stormwater runoff. Also includes cost for UXO work plans and Soil Cover Maintenance Plan. Cost assumed to be 20 percent of the total direct costs.

Construction Contingency

- The construction contingency cost is 20 percent of the cost of the total direct costs.

Health and Safety Equipment and Training

- Costs associated with providing health and safety equipment (i.e., air sampling) and training for use during remediation activities are assumed to be approximately 5 percent of total direct costs.

Legal and Administrative

- Costs associated with any legal and administrative issues associated with implementation of the corrective action such as coordination with Federal, State, and local agencies, and landowners. Costs are assumed to be 5 percent of total direct costs.

Project Management

- Costs associated with providing construction oversight, technical direction, legal and administrative issues, quality control, monthly progress reports, and invoice generation for the project are assumed to be approximately 10 percent of total direct costs.

Annual costs

- Annual cover maintenance includes cover inspection, maintenance of the cover, and surface water management. Maintenance activities include promoting a diverse vegetation community throughout the landfill cover. Periodic site inspections should be conducted to observe for soil erosion, especially in areas identified as having the potential for exposed debris due to erosion. Areas which have erosion and where debris is uncovered will be repaired. Annual costs for engineering, administration, project management, and contingency are also included.

A.1.1.3 Groundwater Monitoring

- Groundwater samples will be collected from 7 wells twice each year.

- A total of 10 samples will be collected each round (one field sample from each well, one field duplicate, one trip blank, and one equipment blank) and analyzed for antimony and VOCs at an off-site laboratory. In addition, the pH and redox potential of groundwater and water level in each well will also be measured.

- Well sampling costs include labor, materials necessary for data analysis, evaluation of site conditions, and recommendations for continuation of yearly reviews or active remediation of groundwater.

- Cost of preparing semiannual reports includes labor and materials necessary for data analysis, evaluation of site conditions, and recommendations for continuation of reviews and monitoring.

A.1.1.4 Land Use Restrictions

- Includes legal and administrative costs associated with obtaining land use restrictions from the Army. These restrictions will not allow construction activities (other than cover maintenance) without a construction health and safety assessment subject to UDEQ review and approval. Costs included with indirect costs.

A.1.1.5 Other Cost Estimating Assumptions

The following are additional general assumptions for development of cost estimates.

- For present worth calculations, the discount rate is based on interest rates on U.S. Treasury Notes and Bonds as presented in the U.S. Office of Management and Budget Circular No. A-94, Appendix C (February 2002). The 30-year rate of 3.9 percent is used for all three alternatives.

- Tables A-1 and A-2 have an inflation adjustment of 10 % to account for inflation that has occurred from when the costs were developed in 1998 (for the Draft CMS) to 2002.

- Each cubic yard of excavated soil weights approximately 1.5 tons.

A.1.2 DETAILED COST ESTIMATES

Tables A-1 through A-3 provide detailed cost estimates for the three alternatives evaluated for SWMU 12/15.

Table A-1: SWMU 12/15 - Alternative 1: Multi-Layer Landfill Cap, Groundwater Monitoring, and Land Use Restrictions

Item	Quantity	Unit	Unit Cost	Total Cost
Direct Capital Costs				
Landfill Cover Design and Installation				
O Pre-Design Investigation				
Geotechnical investigation/testing	120	acres	2,000.00	240,000
Subtotal Pre-Design Investigation				240,000
O Surveying				
Control Survey	20,000	lf	0.82	16,400
Grading Control	120	acres	1,410.00	169,200
As-Built Survey	120	acres	95.00	11,400
Subtotal Surveying				197,000
O Site Preparation				
Well Abandonment	7	ea	5,000.00	35,000
UXO screening for areas of excavation (2 crews)	75	day	3,000.00	225,000
Stormwater Management Basins	16,100	cy	9.15	147,315
Subtotal Site Preparation				408,000
O Site Work				
Clearing	120	acres	669.00	80,280
Excavation, hauling and placement of on-site cut soils for foundation layer	200,000	cy	9.15	1,830,000
Off-site soil fill for foundation layer	400,000	cy	6.00	2,400,000
Gas collection layer: drainage netting, 1/4" thick	4,312,000	sf	0.35	1,509,200
Barrier layer: 40 mil HDPE geomembrane	4,312,000	sf	0.40	1,724,800
Barrier layer: Geosynthetic clay liver (GCL)	4,312,000	sf	0.40	1,724,800
Soil drainage layer: drainage netting, 1/4" thick	4,312,000	sf	0.35	1,509,200
Anchor trench	10,200	lf	0.58	5,916
Protective soil layer, 120 acres x 2.0'	390,000	cy	6.00	2,340,000
Protective vegetative cover layer, 120 acres x 0.5'	100,000	cy	6.50	650,000
Vegetation	120	acres	2,570.00	308,400
Subtotal Site Work				14,083,000
O Gas Management System				
Extraction Wells	90	acres	10,000	900,000
Passive Well Heads	150	ea	750.00	112,500
Subtotal Gas Management System				1,013,000
O Surface Water Control System				
Perimeter Ditches	10,200	lf	10.00	102,000
Down Chutes	4,000	lf	50.00	200,000
Channel Stabilization Base	3,500	lf	102.00	357,000
Channel Stabilization	3,500	lf	492.00	1,722,000
Subtotal Surface Water Control System				2,381,000
Subtotal Direct Capital Costs				**18,330,000**
Indirect Capital Costs				
O Third Party Engineering	120	acre	3,000.00	360,000
O UXO Work Plans	1	ls	50,000.00	50,000
O Health and Safety (1%)				184,000
O Legal and Administrative (1%)				184,000
O Construction Management (3%)				550,000
O Construction Contingency (5%)				917,000
O Inflation adjustment (costs based on 1998 dollars,10 % adjusment to 2002 dollars)				1,833,000
Subtotal Indirect Capital Costs				**4,080,000**
Total Capital Costs				**22,410,000**

Notes

Detailed quantity and unit cost documentation are provided as attatchments to this summary table

Sources:

RS Means Building Construction Cost Data, 1997

RS Means Environmental Remediation Cost Data, 1998

Landfill Closure and Post Closure, Waste Age April 1996

Table A-1: (Continued)

Item	Quantity	Unit	Unit Cost	Total Cost
Annual O&M Costs				
- Inspection	120	acres	75.00	9,000
- Final Cover System	120	acres	750.00	90,000
- Surface Water Managment System	120	acres	600.00	72,000
- Gas Management System	90	acres	500.00	45,000
- Environmental Monitoring System				
Landfill gas	*90*	*acres*	*150.00*	*13,500*
Stormwater	*120*	*acres*	*100.00*	*12,000*
Subtotal Environmental Monitoring System				25,500
- Groundwater Monitoring				
Samples	*20*	*ea*	*1,400.00*	28,000
Data Analysis & Report Preparation	*2*	*ea*	*10,000.00*	20,000
Subtotal Semi-Annual Groundwater Monitoring O&M Costs				48,000
Subtotal Annual O&M				**290,000**
- Engineering, project management and Administration (10%)				29,000
- Contingency (10%)				29,000
Total Annual O&M Costs				**348,000**
Present Worth Annual O&M Costs (30 years @ 3.9% Discount Rate) (1)				**6,330,000**
TOTAL COST OF ALTERNATIVE				**28,800,000**

Notes
Detailed quantity and unit cost documentation are provided as attatchments to this summary table
Sources:
RS Means Building Construction Cost Data, 1997
RS Means Environmental Remediation Cost Data, 1998
Landfill Closure and Post Closure, Waste Age April 1996

(1) Discount Rates based on U.S. Office of Management and Budget Circular No. A-94, Appendix C (February 2002)

Key to unit abbreviations

ea	each
cy	cubic yard
hr	hour
lf	linear foot
ls	lump sum
sf	square foot

Table A-2: SWMU 12/15 - Alternative 2: Evapotranspiration Landfill Cover, Groundwater Monitoring, and Land Use Restrictions

Item	Quantity	Unit	Unit Cost	Total Cost
Direct Capital Costs				
Landfill Cover Design and Installation				
O Pre-Design Investigation				
Geotechnical investigation/testing	120	acres	2,000.00	240,000
Subtotal Pre-Design Investigation				240,000
O Surveying				
Control Survey	20,000	lf	0.82	16,400
Grading Control	120	acres	846.00	101,520
As-Built Survey	120	acres	95.00	11,400
Subtotal Surveying				130,000
O Site Preparation				
Well Abandonment	7	ea	5,000.00	35,000
UXO screening for areas of excavation (2 crews)	75	day	3,000.00	225,000
Stormwater Management Basins	16,100	cy	9.15	147,315
Subtotal Site Preparation				408,000
O Site Work				
Clearing	120	acres	669.00	80,280
Excavation, hauling and placement of on-site cut soils for foundation layer	200,000	cy	9.15	1,830,000
Off-site soil fill for foundation layer	400,000	cy	6.00	2,400,000
Barrier Soil Layer, 90 acres x 1.5'	220,000	cy	11.50	2,530,000
Anchor trench	10,200	lf	0.58	5,916
Protective soil layer, 120 acres x 2.0'	390,000	cy	6.00	2,340,000
Protective vegetative cover layer, 120 acres x 0.5'	100,000	cy	6.50	650,000
Vegetation	120	acres	2,570.00	308,400
Subtotal Site Work				10,145,000
O Gas Management System				
Passive Well Heads	70	ea	750.00	52,500
Subtotal Gas Management System				52,500
O Surface Water Control System				
Perimeter Ditches	10,200	lf	10.00	102,000
Down Chutes	4,000	lf	50.00	200,000
Channel Stabilization Base	3,500	lf	102.00	357,000
Channel Stabilization	3,500	lf	492.00	1,722,000
Subtotal Surface Water Control System				2,381,000
Subtotal Direct Capital Costs				**13,360,000**
Indirect Capital Costs				
O Third Party Engineering	120	acre	3,000.00	360,000
O UXO Work Plans	1	ls	50,000.00	50,000
O Health and Safety (1%)				134,000
O Legal and Administrative (1%)				134,000
O Construction Management (3%)				401,000
O Construction Contingency (5%)				668,000
O Inflation adjustment (costs based on 1998 dollars,10 % adjusment to 2002 dollars)				1,336,000
Subtotal Indirect Capital Costs				**3,090,000**
Total Capital Costs				**16,450,000**

Notes

Detailed quantity and unit cost documentation are provided as attatchments to this summary table

Sources:

RS Means Building Construction Cost Data, 1997

RS Means Environmental Remediation Cost Data, 1998

Landfill Closure and Post Closure, Waste Age April 1996

Table A-2: (Continued)

Item	Quantity	Unit	Unit Cost	Total Cost
Annual O&M Costs				
- Inspection	120	acres	75.00	9,000
- Final Cover System	120	acres	600.00	72,000
- Surface Water Managment System	120	acres	550.00	66,000
- Gas Management System	90	acres	50.00	4,500
- Environmental Monitoring System				
Landfill gas	*90*	*acres*	*25.00*	*2,250*
Stormwater	*120*	*acres*	*100.00*	*12,000*
Subtotal Environmental Monitoring System				14,250
- Groundwater Monitoring				
Samples	*20*	*ea*	*1,400.00*	28,000
Data Analysis & Report Preparation	*2*	*ea*	*10,000.00*	20,000
Subtotal Semi-Annual Groundwater Monitoring O&M Costs				48,000
Subtotal Annual O&M				**214,000**
- Engineering and Administration (10%)				21,400
- Contingency (10%)				21,400
Total Annual O&M Costs				**257,000**
Present Worth Annual O&M Costs (30 years @ 3.9% Discount Rate) (1)				**4,680,000**
TOTAL COST OF ALTERNATIVE				**21,200,000**

Notes
Detailed quantity and unit cost documentation are provided as attatchments to this summary table
Sources:
RS Means Building Construction Cost Data, 1997
RS Means Environmental Remediation Cost Data, 1998
Landfill Closure and Post Closure, Waste Age April 1996

(1) Discount Rates based on U.S. Office of Management and Budget Circular No. A-94, Appendix C (February 2002)

Key to unit abbreviations	
ea	each
cy	cubic yard
hr	hour
lf	linear foot
ls	lump sum
sf	square foot

Table A-3: SWMU 12/15 - Alternative 3: Upgrade Existing Soil and Vegetative Cover, Groundwater Monitoring, and Land Use Restrictions

Item	Quantity	Unit	Unit Cost	Total Cost
Direct Capital Costs				
Upgrade Existing Soil and Vegetative Cover				
O Surveying (areas regraded or new soil cover only)				
Control Survey	2,000	lf	1.30	2,600
Grading Control	15	acres	405.00	6,075
As-Built Survey	15	acres	405.00	6,075
Subtotal Surveying				15,000
O Site Preparation				
Silt fence	2,000	lf	1.91	3,820
UXO screening for areas of excavation (2 crews)	10	day	3,000.00	30,000
Subtotal Site Preparation				34,000
O Site Work				
Moblization/Demolibization	1	ls	20,000.00	20,000
Stabilization fabric for access roads	4,400	sy	1.04	4,576
Gravel (3" thick layer) for access roads	4,400	sy	2.73	12,012
Collect surface debris and place within central cover areas	20	day	3,000.00	60,000
Clearing of areas for soil cover and regrading	15	acres	669.00	10,035
Haul and place soil for 2 foot cover layer (10 acres)	32,000	cy	8.36	267,520
Excavation for ponding areas	1,800	cy	16.31	29,358
Hauling and placement of soil fill for ponding areas	11,300	cy	8.36	94,468
Hauling and placement of 3 inches topsoil (20 acres)	8,060	cy	25.23	203,354
Vegetation	30	acres	3,480.00	104,400
Subtotal Site Work				806,000
O Surface Water Controls				
Miscellaneous grass drainage swales	1,000	lf	11.72	11,720
Rock cover, rip-rap (10 to 100 lb. pieces)	1,000	cy	21.30	21,300
Stabilization fabric for swales	3,000	sy	1.04	3,120
Subtotal Surface Water Controls				37,000
Subtotal Landfill Cover Capital Costs				**900,000**
Indirect Capital Costs				
O Engineering Design (includes evaluation of cover, UXO Work Plans, and Maintenance Plan) (20%)				180,000
O Health and Safety (5%)				45,000
O Legal and Administrative (5%)				45,000
O Construction Management (10%)				90,000
O Construction Contingency (20%)				180,000
Subtotal Indirect Capital Costs				**540,000**
Total Capital Costs				**1,440,000**

Notes

Detailed quantity and unit cost documentation are provided as attatchments to this summary table

Sources:

RS Means Building Construction Cost Data, 2003

RS Means Environmental Remediation Cost Data Unit Price, 2002

Table A-3: (Continued)

Item	Quantity	Unit	Unit Cost	Total Cost
Annual O&M Costs				
- Inspection	100	hr	60.00	6,000
- Final Cover System - labor / equipment	80	hr	140.00	11,200
- Final Cover System -materials	1	ls	2,000.00	2,000
- Vegetation maintenance - labor	60	hr	50.00	3,000
- Vegetation -materials	1	ls	500.00	500
- Groundwater Monitoring				
Samples	*20*	*ea*	*1,400.00*	28,000
Data Analysis & Report Preparation	*2*	*ea*	*10,000.00*	20,000
Subtotal Semi-Annual Groundwater Monitoring O&M Costs				48,000
Subtotal Annual O&M				**70,700**
- Engineering and Administration (10%)				7,070
- Contingency (10%)				7,070
Total Annual O&M Costs				**85,000**
Present Worth Annual O&M Costs (30 years @ 3.9% Discount Rate) (1)				**1,550,000**
TOTAL COST OF ALTERNATIVE				**3,000,000**

Notes

Detailed quantity and unit cost documentation are provided as attatchments to this summary table

Sources:

RS Means Building Construction Cost Data, 2003

RS Means Environmental Remediation Cost Data Unit Price, 2002

(1) Discount Rates based on U.S. Office of Management and Budget Circular No. A-94, Appendix C (February 2002)

Key to unit abbreviations

ea	each
cy	cubic yard
hr	hour
lf	linear foot
ls	lump sum
sf	square foot

ATTACHMENT 1

SWMU 12/15: Estimated Quantities for CMS Cost Estimate

Attachment 1
SMWU 12/15: Estimated Quantities for CMS Cost Estimate

Item				
Area of Landfill (a)	2,920,000	sf	70	acres
Area of Cover (surface view) (b)	5,230,000	sf	120	acres
Area of Barrier Layer Cap (c)	3,920,000	sf	90	acres
Perimeter of cap (c)	10,200	lf		
Channel Length (d)	3,500	lf		

Layer Type	**ET Cover**		**Multi-Layer Cap**		
	Thickness (ft)	*Volume* (cy)	*Thickness* (ft)	*Volume* (cy)	*Area* (sf)
CUT FILL QUANTITIES FOR FOUNDATION LAYER					
Total Cut and Fill Soils Required (e)		600,000		600,000	
Cut soils excavated from landfill (f)		200,000		200,000	
Fill required from off-site (g)		400,000		400,000	
QUANTITIES FOR CAP ABOVE FOUNDATION LAYER					
Barrier soil layer, 90 acres (h)	1.5	220,000	NA	NA	NA
Gas collection within foundation layer, 90 acres (c, i)	NA	NA	0.02	-	4,312,000
GM/GCL, 90 acres (c, i)	NA	NA	0.06	-	4,312,000
Drainage, 90 acres (c, i)	NA	NA	0.02	-	4,312,000
Protective soil, 120 acres (h)	2	390,000	2	390,000	
Protective cover, 120 acres (h)	0.5	100,000	0.5	100,000	
Anchor trench (lf) (c)		10,200		10,200	
Channel length (lf) (d)		3,500		3,500	
Stormwater basins (cy) (j)		16,100		16,100	

(a) Source: Final Exploration Trenching Report For SWMU 12/15 (MWH, 2002)
(b) Source: Estimated limit of protective cover (area of barrier layer cap plus assumed additional 30 acres for providing uniform but not overly steep surface grade from cap to surrounding existing grade).
(c) Source: Figure 6-6: SWMU 12/15 estimated landfill cap boundary (area of barrier layer)
(d) Source: Figure 6-6: Approximate length of channel center line
(e) Cut and fill soil volume for foundation soil layer (i.e., to smooth out existing topography and provide for several feet of soil beneath barrier layer. For cost estimating purposes, the estimated quantity of cut and fill soil is roughly assumed to be area of the cap times 4 feet).
(f) Soil excavated and moved for cut portion of cut and fill quantity is assumed to be 36 percent of the total cut and fill quantity required.
(g) Soil needed for fill portion of cut and fill quantity is assumed to be 66 percent of the total cut and fill quantity required.
(h) Layer thickness (ft.)*43,560(sf/acre)*Cap Area (acres) / 27(cf/cy)
(i) Geosynthetic component area = Area within the landfill cap * 1.1 for wasteage
(J) Stormwater basin area = Limit of Protective Cover (120 acres)*3600/27(cf/acre)

ATTACHMENT 2

Sanitary Landfill/Pesticide Disposal Area (SWMU 12/15)--Documentation of Costs

Attachment 2: Sanitary Landfill / Pesticide Disposal Area (SWMU 12/15)--Documentation of Costs
(Continued)

Item/Calculation	Unit cost
LANDFILL CAP (ALTERNATIVES 1 AND 2)	
Costs presented in this attachment were developed in 1998. To account for time passed between Draft and Final CMS Report, the cost tables A-1 and A-2 continue to use these unit costs but have an inflation adjustment to bring unit costs up to 2002. This done only for capital costs.	
Pre-Design Investigation Geotechnical investigation/testing	$ 2,000 /acre
SURVEYING	
Topographic Survey: 1 ft contours aerial survey with ground control $ 200 / acre	$ 200 /acre
Control Survey: Property lines (preliminary stake out) $ 0.82 / lf	$ 0.82 /lf
Grading Control: Conventional topographic survey $ 282 / acre / soil layer	$ 282 /acre /soil layer
As-Built Survey: 1 ft contours aerial survey with ground control $ 68 /acres x 1.4 = $ 95 /acre	$ 95 /acre
SITE PREPARATION	
Well abandonment: <u>labor</u> 36 hours x 20 / hour = $ 720 <u>waste handling</u> 2 drums x 160 / drum = $ 320 <u>subcontracts</u> 1 well x 3000 / well = $ 3,000 <u>equipment</u> 1 ea x 300 / ea = $ 300 <u>Subtotal per well</u> $ 4,340 Abandon 7 wells: (N-112-88, N-115-88, N-116-88, N-114-88, N -119-88, N-144-93, N-150-97) <u>Subtotal 7 wells</u> $ 30,380 <u>mobilization</u> 1 ea x 5000 / ea = $ 5,000 <u>Subtotal well abandonment</u> $ 35,380 $ 35,380 / 7 = $ 5,054 Rounddown $ 5,000 /well	$ 5,000 /well

Attachment 2: Sanitary Landfill / Pesticide Disposal Area (SWMU 12/15)--Documentation of Costs
(Continued)

Item/Calculation	Unit cost
Excavation, hauling and placement of on-site cut soils: Common excavation (backhoe, hydraulic crawler mount 3 cy bucket) $ 2.01 / cy Hauling: 16.5 CY dump trailer, 1 mile roundtrip $ 2.15 / cy Grading at dump by dozer: $ 1.22 / cy Compaction backfill, 6" to 12" lifts, sheepsfoot roller: $ 1.77 / cy add contingency for excavation within landfill areas $ 2 cy subtotal exc., hauling, placement of cut soils $ 9.15 cy	$ 9.15 /cy NOTE: Assumption here is that excavation is permitted in most parts of landfill
SITE WORK Clearing: Medium brush without grub, clearing $ 125 / acre x 120 acres = $ 15,027 Scraper 22cy, 623, grubbing haul 1 mile 1.01 / cy Assume remove 8 inches over 20% of cover ar = 32 acres 32 acres x 43,560 43560 / acre = 1,393,920 sf 1,393,920 sf x 0.67 ft = 929,280 cf 929,280 cf / 27 = 34,418 cy 1.01 / cy x 34,418 cy = $ 34,774 Light brush without grub, chipping $ 951 / acre x 32 acres = $ 30,436 ls Chipped wood disposal--assume beneficial reuse on-post at no cost to project <u>Subtotal clearing</u> $ 80,237 ls $ 80,237 ls / 120 acres = $ 669 acre	$ 669 /acre
Excavation, hauling and placement of on-site cut soils for foundation layer: Common excavation (backhoe, hydraulic crawler mount 3 cy bucket) $ 2.01 / cy Hauling: 16.5 CY dump trailer, 1 mile roundtrip $ 2.15 / cy Grading at dump by dozer: $ 1.22 / cy Compaction backfill, 6" to 12" lifts, sheepsfoot roller: $ 1.77 / cy add contingency for excavation within landfill areas $ 2 cy subtotal exc., hauling, placement of cut soils $ 9.15 cy	$ 9.15 /cy NOTE: Assumption here is that excavation is permitted in most parts of landfill

Attachment 2: Sanitary Landfill / Pesticide Disposal Area (SWMU 12/15)--Documentation of Costs (Continued)

Item/Calculation	Unit cost
Off-site soil fill for foundation Layer: Common excavation (backhoe, hydraulic crawler) multi by 70% due to excavation occuring at borrow pit $ 1.41 / cy Hauling: 16.5 CY dump trailer, 2 mile roundtrip $ 2.66 / cy Grading at dump by dozer: $ 1.22 / cy Compaction backfill, 6" to 12" lifts, sheepsfoot roller: $ 1.77 / cy subtotal exc., hauling, placement of cut soils $ 7.05 cy multi by 85% due to large size of earthwork $ 5.99	$ 6.0 /cy
Gas collection layer (Drainage netting, 1/4" thick HDPE, geotextile fabric one side) Multi-layer cap only	$ 0.35 /sf
Barrier layer (geosynthetic clay liner) Multi-layer cap only	$ 0.40 /sf
Barrier layer (flexible membrane liner--40mil HDPE) Multi-layer cap only	$ 0.40 /sf
Soil drainage layer (Drainage netting, 1/4" thick HDPE, geotextile fabric one side) Multi-layer cap only	$ 0.35 /sf
Barrier layer (1.5 ft soil ammended with bentonite) ET cover only	$ 11.5 /cy
Anchor trench	$ 0.58 /lf
Protective soil layer: see cost above for foundation layer	$ 6.0 /cy
Protective vegetated soil cover layer: Assume topsoil is stripped from landfill surface: Common excavation (backhoe, hydraulic crawler mount 3 cy bucket) $ 2.01 / cy Hauling: 16.5 CY dump trailer, 1 mile roundtrip $ 2.15 / cy Grading at dump by dozer: $ 1.22 / cy Compaction backfill, 6" to 12" lifts, sheepsfoot roller: $ 1.77 / cy add contingency for additional off-site topsoil $ 0.5 cy subtotal exc., hauling, placement of cut soils $ 7.65 cy multi by 85% due to large size of earthwork $ 6.5	$ 6.5 /cy
Vegetation: Hydro or air seeding for large areas, incl. seed and fertilizer 49 / msf Multiply by 20% for tilling, etc. $49 * 1.2 = 59 $2,570 / acre	$2,570 /acre

Attachment 2: Sanitary Landfill / Pesticide Disposal Area (SWMU 12/15)--Documentation of Costs (Continued)

Item/Calculation					Unit cost
O GAS MANAGEMENT SYSTEM					
Extraction wells:					$ 10,000 /acre
Passive wells:					$ 750 each
O SURFACE WATER CONTROL SYSTEM					
Perimeter ditches:					$ 10 /lf
Down chutes:					$ 50 /lf
Channel Stabilization, Base					$ 102 /lf
	Structural fill - assume cut and fill volumes for site work include the channel				
	Drainage material:				
	[1*1*15*sqr(10)]*2	=	95 cf / lf 3.5 cy / lf		
	well graded granular material				
	Borrow, buy and load at pit, haul 2 miles RT, and spread with 200 hp dozer Bank run gravel		$ 9.13 cy		
	Compaction backfill, 6" to 12" lifts, sheepsfoot roller:		$ 1.91 cy		
	subtotal		$ 11.04 cy $ 11 cy		
	$ 11 cy * 3.5 cy / lf	=	$ 39 cy		
	Soil-Cement roadway				
	Soil cement plating				
	Enviroset pre-mix stabilization Common borrow to site Haul from on-site plant dozer placement sheepsfoot compaction		$ 22 ton 8 ton 3 ton 0.8 ton 3 ton		
	subtotal		$ 38 ton		
	(Assumes 1.5 tons per cubic yard soil)		$57 cy		
	volume [20' wide * 1.5' thick}	=	30 cf 1.11 cy / lf		
	$ 57 cy x 1.11 cy / lf	=	$ 63 lf		
	SUBTOTAL		$ 102 lf		

Attachment 2: Sanitary Landfill / Pesticide Disposal Area (SWMU 12/15)--Documentation of Costs (Continued)

Item/Calculation	Unit cost
Channel slope stabilization:	$ 492 /lf
Embankment cut and fill - assume soil volumes for site work include the channel embankment.	
Soil cement plating	
Enviroset pre-mix stabilization $ 22 ton	
Common borrow to site 8 ton	
Haul from on-site plant 3 ton	
dozer placement 0.8 ton	
sheepsfoot compaction 3 ton	
subtotal $ 38 ton	
(Assumes 1.5 tons per cubic yard soil) $57 cy	
volume [1*12 + 2*25*sqr(10) + .5*2*9 +6*9] * 1 = 233 cf; 8.63 cy / lf	
$ 57 cy x 8.63 cy / lf = $ 492 lf	
total: channel slope stabilization $ 492 lf	
O THIRD PARTY ENGINEERING	
Third party engineering	
Multi-layer cap:	$ 3,000 /acre
ET cover	$ 3,000 /acre
O CONSTRUCTION CONTINGENCY	
Construction contingency of 5 % of est. landfill closure costs is considered appropriate for an estimate of this magnitude and this level of detail.	
O HEALTH AND SAFETY	
Health and Safety costs of 1% of landfill closure costs is estimated.	
O CONSTRUCTION MANAGEMENT	
Construction management costs of 3% is standard practice for large civil/remedial works	
LANDFILL POST CLOSURE	
O ANNUAL OPERATIONS AND MAINTENANCE	
INSPECTION	$ 75 /acre
FINAL COVER SYSTEM	
Multi-layer cap:	$ 750 /acre
ET cover-assumed smaller because repairs expected to be less expensive:	$ 600 /acre
SURFACE WATER MANAGEMENT	
Multi-layer cap:	$ 600 /acre
ET cover-assumed smaller because no soil drainage layer to maintain:	$ 550 /acre
GAS MANAGEMENT SYSTEM	
Multi-layer cap:	$ 500 /acre
ET cover-assumed smaller only include small number of passive wells:	$ 50 /acre
ENVIRONMENTAL MONITORING SYSTEM	
Groundwater Monitoring - presented in main cost appendix	
Landfill gas	
Multi-layer cap:	$ 150 /acre
ET cover-assumed smaller only include small number of passive wells:	$ 25 /acre
Stormwater	$ 100 /acre
O ENGINEERING AND ADMINISTRATION	
Engineering and Administration costs of 10% is standard practice for remedial works O&M	
REFERENCES	
-- ENVIRONMENTAL REMEDIATION COST DATA--UNIT PRICE 4TH ANNAUL EDITION,1998 (ECHOS 98); PRICES REFLECT 0.941 MULTIPLIER FOR SLC, UTAH	
-- BUILDING CONSTRUCTION COST DATA--55TH ANNUAL EDITION, 1997 (MEANS 97); PRICES REFLECT 0.871 or 0.941 MULTIPLIER FOR SLC, UTAH	
-- LANDFILL CLOSURE AND POST-CLOSURE: FUTURE COSTS NOT TO BE FORGOTTEN A.F. NICKODEM, D.S. VLADIC, AND S.D. MENOFF. WASTE AGE, APRIL 1996	
-- BUDGETARY VENDOR QUOTES BY TELEPHONE AS DOCUMENTED	

APPENDIX B

Landfill Cap/Cover Selection Analysis

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APPENDIX B
Landfill Cap/Cover Alternative Analysis
Sanitary Landfill/Pesticide Disposal Area (SWMU 12/15)

This Section presents an evaluation of the existing landfill cover at SWMU 12/15 and develops a conceptual design for three types of cover systems.

B.1 REGULATORY BASIS OF COVER SYSTEMS

The Sanitary Landfill/Pesticide Disposal Area (SWMU 12/15) covers approximately 70 acres (MWH, 2002) of open land previously used for the land disposal of waste generated at TEAD. Buried debris at the landfill includes construction debris and solid municipal and industrial-type waste. The Sanitary Landfill was never permitted. Hazardous waste was not deposited in the landfill after October 1980, when the RCRA Management Plan was implemented.

UDEQ has regulatory decision authority over SWMU 12/15 as part of implementing TEAD's Post Closure Permit. Because the landfill received no hazardous waste after November 19, 1980, *Federal and Utah Interim Status Standards for Hazardous Waste Landfills* [(40 CFR Part 265) and (UAC R315-7)] do not apply at SWMU 12/15. Because of these statutes and an agreement between TEAD and UDEQ when SWMUs were designated as needing post closure care, *Interim Status Requirements for Hazardous Waste Landfills* (UAC R315-7) need not be considered as relevant or appropriate at SWMU 12/15. State and Federal landfill closure and final cover requirements are not applicable, but UAC R315-101 cleanup requirements still apply.

RCRA requirements for hazardous wastes would be applicable if the response activity constitutes treatment, storage, or disposal, as defined under RCRA. This may include activities that disturb contaminated material and affect any decision regarding cut and fill of buried debris. However, movement within a unit should not constitute disposal or placement.

B.2 MILITARY LANDFILLS - ROD REVIEW

The closure of permitted landfills at military facilities is often governed by Federal and state regulations applicable to municipal solid waste (MSW), sanitary, and other nonhazardous waste landfills. These nonhazardous waste landfills will hereafter be referred to as sanitary landfills. The Federal regulations that apply to the closure of sanitary landfills are presented in 40 CFR Part 258, Subpart F (Closure and Post-Closure Care). These regulations were established by EPA under Subtitle D of RCRA. State of Utah regulations that apply to the closure of sanitary landfills are present in R315-303-3(4) of the Utah Administrative Code. In general, the Federal and State of Utah regulations for the closure of sanitary landfills are identical. The State of Utah has authority from EPA to regulate sanitary landfills.

The remedies selected in Records of Decision (RODs) for 51 landfills at 24 military installations are summarized in the *Application of the CERCLA Municipal Landfill Presumptive Remedy to Military Landfills (Interim Guidance)* Directive No. 9355.0-62-FS, EPA/540/F-96/007, Pb96-9633-07, April 1996. This document shows that the types of wastes disposed in military landfills are generally similar to those disposed in sanitary landfills. The document also shows that the types of source containment actions typically taken to close sanitary landfills are often appropriate for military landfills as well. According to this document, most sanitary and military landfills contain predominantly nonhazardous materials such as residential and commercial trash, construction debris, and nonhazardous industrial wastes. Smaller amounts of hazardous materials such as paints, solvents, and pesticides are also generally present in these landfills. When military landfills contain high-hazard, military-specific wastes such as radioactive materials, munitions, and chemical warfare agents, additional specialized remedial actions are required. In the case of SWMU 12/15, such military-specific wastes are not reported to be present in the landfill.

A review of the ROD summaries presented in the above EPA document and the complete RODs for several of the military landfills showed that a wide variety of landfill covers and caps have been used (or selected for use) at military landfills. These landfill covers and caps range from relatively simple soil covers designed to comply with regulations for Subtitle D sanitary landfills to sophisticated multi-layered caps designed to comply with regulations for Subtitle C hazardous waste landfills. In addition to the landfill covers and caps, a wide variety of other remedial measure have also been taken at the military landfills. One or more of the following environmental control systems have also been used in closing many of the military landfills: (1) leachate collection and monitoring systems; (2) landfill gas collection and monitoring systems; and 93) soil vapor extraction systems. At several of the landfills, however, none of these systems was considered to be necessary. At most of the military landfills, groundwater remediation and monitoring systems and surface water management systems have also been used.

Examples of military landfills where relatively simple landfill covers have been selected as remedies in the RODs are listed below:

- Robins Air Force Base in Warner Robins, Georgia. An existing soil cover on a 45-acre landfill was renovated with additional soil and clay materials. The renovated cover was at least 2-feet thick in all locations. The selected remedy also included leachate controls.

- Plattsburg Air Force Base in Plattsburg, New York. A 6-inch thick compacted soil layer was placed over an existing 12-inch thick soil cover at a 13.7-acre landfill. In addition, a 6-inch layer of topsoil was placed above the compacted soil.

- Naval Reactor Facility in Idaho. A 2-foot thick "native soil cover" was used at three landfills with a combined area of approximately 30 acres. The ROD states "The Agencies have determined that a native soil cover is adequate to prevent direct contact with the landfill contents; in an arid climate, use of an impervious layer does not necessarily provide a significant added benefit." The selected remedy also included landfill gas monitoring.

- Williams Air Force Base in Arizona. A 2-foot thick soil cover was used at a 9-acre landfill. The ROD indicated that allow permeability cover was not needed because of the arid climate at the site location.

- Fort Dix in Wrightstown, New Jersey. A low-permeability multi-layered cap was used over 50 acres of the landfill. However, a 2-foot thick soil cover was selected in the ROD for the remaining 76 acres of the landfill. This soil cover was considered to be adequate for the older portions of the landfill, which were assumed "to be exhausted of any hazardous leachable material". The selected remedy also included a landfill gas monitoring and control system.

An ongoing study by Sandia National Laboratories (Finding a Better Cover, Stephen Dwyer, *Civil Engineering*, January 2001) provides additional support for foregoing an impermeable barrier as part of the final cover. This investigation is evaluating the long-term performance of six different cover designs in terms of water balance performance, ease of construction, and cost. The study will provide a recommendation for the best landfill cover design for arid climates.

Results released three years into the study indicated that by the third year, an "evapotranspiration cover," consisting of a 75-cm (30-inch) layer of compacted soil topped by a 15-cm (6-inch) layer of loosely placed vegetated soil performed better than a cover with a Subtitle C compacted clay layer, a geosynthetic clay liner, or RCRA Subtitle D cap.

B.3 PRELIMINARY EVALUATION OF EXISTING LANDFILL COVER

This section presents an evaluation of the existing landfill cover in terms of topography, drainage patterns, surface debris, and vegetation. The information presented is referenced from previous reports and provides a general understanding of the current condition of the landfill cover. This evaluation is not intended as a basis for design calculations.

B.3.1 Site Topography and Drainage Patterns

The following discussion is based on the topographic survey map for the SWMU 12/15 Sanitary Landfill issued in November 2000 by the USACE. At the sanitary landfill, the elevation gradually decreases from an elevation of about 4,810 ft. above mean sea level (msl) in the southeast corner to an average elevation in the northwest area of approximately 4,710 ft. above msl. This 100 ft change in elevation takes place over a horizontal distance of approximately 5,800 ft; therefore, the overall average slope across the entire landfill is about 2%. However, the presence of an arroyo through the landfill results in areas with larger slopes.

The majority of the landfill terrain is flat or gently sloping (i.e., 3 to 8 feet of vertical drop per 100 horizontal feet). The remaining area of the sanitary landfill consists of the arroyo which runs through the middle of the landfill from the southeast to the northwest. The slope of the channel bed ranges from 0 to approximately 6%. Much of the arroyo has steep banks with slopes ranging from approximately 16% to 100% with the majority of the slopes equaling roughly 30%. The steepest slopes are located along the southwest banks of the arroyo in the north-central area of the landfill. The arroyo's banks have a vertical drop of up to 30 feet.

A preliminary estimate of the drainage areas for the landfill was performed based on the topographic survey map. The general slope of SWMU 12/15 and the surrounding area is from the east to west. However, water flow from the streambed upgradient and east of the landfill is diverted around the landfill. In addition, the road on the eastern boundary of SWMU 12/15 prevents most of the potential off-site runoff from the east onto the landfill.

The northern portion of the landfill drains into the arroyo. The size of the drainage area is approximately 80 acres, and includes a significant amount of land east of the landfill boundary. The southeast leg of the landfill has a very uneven topography with several depressions where stormwater runoff will collect. The west-central part of the landfill (i.e., just east of the inactive sewage evaporation ponds) also has a very uneven topography with several depressions for stormwater runoff to drain to. The inactive sewage evaporation basins are flat but slightly depressed from surrounding land. The southwest part of the landfill slopes southwest and runoff will flow in that direction offsite.

B.3.2 Soil Survey

The Soil Survey (SS) of Tooele Area, Utah (USDA, 2000) identified three major soil units at SWMU 12/15. The predominant soil unit is Hiko Springs gravelly sandy loam, 2 to 4 percent slopes. The survey describes this soil as very deep, well drained soil, with moderately rapid permeability (2 to 6 inches per hour). Typically the surface layer is pale brown gravelly sandy loam about 4 inches thick. The subsurface soil to a depth of 60 inches or more is very pale brown gravelly sandy loam. The clay fraction is 10 to 18 percent and the pH ranges from 7.9 to 9. Available water capacity is moderate (about 5 to 5.5 inches). The organic matter content in the surface layer is 0.5 to 1 percent. Effective rooting depth is 60 inches or more. Runoff is slow, and the hazard of water erosion is slight. The hazard of wind erosion is moderate. The hydrologic group is B. Conditions are favorable for water management terraces and diversions but not grass waterways (USDA, 2000). This soil unit has a potential plant community of about 50 percent perennial grasses, 5 percent forbs, and 45 percent shrubs. The survey identified predominant plant species to be Indian ricegrass, shadscale, winterfat, rabbitbrush, and bud sagebrush (USDA, 2000).

The soil survey identified the arroyo as a Pits soil unit, due to the excavation that has occurred there. It notes that due to excavation, the Pits soil unit supports few plants. Areas within the arroyo where extensive soil disturbance occurred are most likely covered with soil fill from surrounding areas, which is more suitable for plants. This soil unit is surrounded by the Hiko Springs unit described above.

In the southwestern portion of SWMU 12/15, the soil survey identified the soil unit as Medburn fine sandy loam, 2 to 8 percent slopes. The survey describes this soil as very deep, well drained soil with moderately rapid permeability. Typically, the surface layer is pale brown fine sandy loam about 4 inches thick. The subsurface soil is light yellowish brown fine sandy loam about 37 inches thick. The clay fraction is 5 to 18 percent and the pH ranges from 7.9 to 9. Available water capacity is moderate (about 5 to 7 inches). The organic matter content in the surface layer is 1 to 2 percent. Effective rooting depth is 60 inches or more. Runoff is medium, and the hazard of water erosion is moderate. The hydrologic group is B. The hazard of wind erosion is also moderate (USDA, 2000). This soil unit has a potential plant community of about 50 percent perennial grasses, 15 percent forbs, and 35 percent shrubs. The SS identified predominate plant species to be bluebunch wheatgrass, Wyoming big sagebrush, Indian ricegrass, Douglas rabbitbrush, cheatgrass, and bottlebrush squirretail (USDA, 2000).

B.3.3 Preliminary Evaluation of Surface Debris

As shown on Figure B-1, the SWMU 12/15 Exploration Trenching Report (MWH, 2002) identified three large areas of concrete rubble and surface debris within the landfill. In addition, the report identified surface debris at a large number of the trench locations. These trenches were primarily around the perimeter of the landfill. The debris most commonly identified was wood, metal fragments, and concrete, with fewer occurrences of cinder blocks, asphalt, sheet metal, broken glass, pop cans, and foam. A site visit by URS in June 2002 also identified several smaller areas of concrete and debris within the periphery of the landfill.

The table below summaries the estimated area of surface debris based on this data. The estimate is preliminary and a detailed site survey would be necessary to more accurately determine the total area and amount of exposed surface debris.

PRELIMINARY ESTIMATE OF SURFACE DEBRIS - SWMU 12/15

Site Location	Approximate Area[1] (Acres)
Concrete rubble, center of landfill[2]	2.75
Surface debris, south central landfill[2]	0.7
Surface debris, south east landfill[2]	0.77
Concrete rubble within Inactive Sewage Evaporation Basin[3]	2.8
Miscellaneous areas of surface debris based on site walk[3]	2
Debris found at trench locations[4]:	
30 Moderate debris - 2000 ft^2 x 30 = 60,000 ft^2	1.5
30 Minor debris - 800 ft^2 x 30 = 24,000 ft^2	0.5
Subtotal:	11
Contingency (50%)	5.5
Total:	17

1. Areas are based on limited site observations and this information is intended only for purposes of providing a preliminary estimate to assist with evaluation of corrective measures alternatives.
2. Areas based on Plate 1 of the SWMU 12/15 Exploration Trenching Report (MWH, 2002).
3. Based on site walk performed by URS in June 2002. A debris survey was not part of site walk.
4. Estimated by multiplying the number of trenches with moderate surface debris by 2000 ft^2 and minor surface debris by 800 ft^2. Number of trenches with surface debris as per Table 2-1 of Trenching Report (MWH, 2002). Area of 2000 ft^2 and 800 ft^2 per trench is speculative.

B.3.4 Site Vegetation

This section presents an evaluation of the vegetation at SWMU 12/15 and presents a discussion on the re-establishment of vegetation following grading activities.

B.3.4.1 Vegetation Survey

Vegetation is a major component of soil stability. The SWERA included an evaluation of the vegetation communities at TEAD. The general range types for SWMU 12/15 were identified as pinon-Utah juniper with western portions of the SWMU within a zone of Wyoming big sagebrush (Rust E&I, 1997). A vegetation survey conducted in 1994 identified 19 species at SWMU 12/15. It should be noted that the SWERA survey consisted of five point-intercept transects randomly placed through the SWMU. Because of the large size of the landfill, additional species may also be present that were not identified. Two species were shrubs/half shrubs, 7 were grasses, and 10 were forbs. Of the 19 species, 10 are native and 9 are introduced from Europe, Eurasia, or the Mediterranean area. The dominant species identified were two introduced species, white sweetclover (17 percent of total), cheatgrass (16 percent). The next most dominant species was curlycup gumweed (7 percent), a native forb found in disturbed areas, along roadsides, and in dry pastures. Prostrate knotweed, an introduced annual forb, and purple three-awn, a native bunchgrass, were each 3 percent of the total. The remaining 14 species contributed 2 percent or less individually (Rust E&I, 1997).

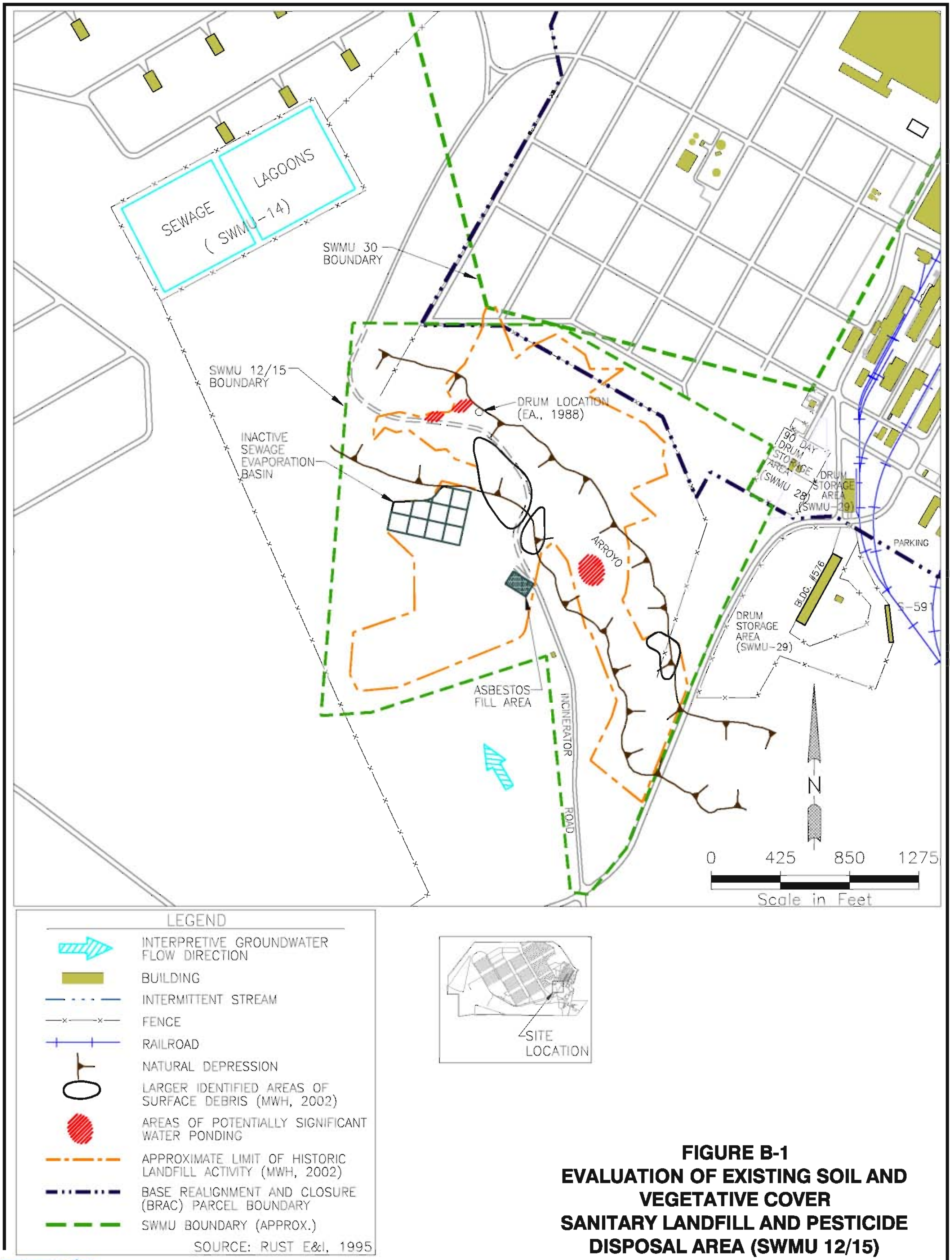


FIGURE B-1
EVALUATION OF EXISTING SOIL AND VEGETATIVE COVER
SANITARY LANDFILL AND PESTICIDE DISPOSAL AREA (SWMU 12/15)
TOOELE ARMY DEPOT

URS

The SWERA estimated that in 1994 the total vegetated area of SWMU 12/15 was less than 60 percent. Of the vegetation, 72 percent was comprised of introduced annual species, and 15 percent was perennial native species. Annual forb species were also a major component of the plant community at the SWMU.

A site walk conducted in June 2002 estimated that the total vegetated area of the SWMU is higher than 60 percent but a vegetation survey would be necessary to determine the current percentage and types of vegetation. The dominant species noted in the summer of 2002 were cheatgrass, sagebrush, rabbitbrush, and perennial bunch grasses such as squirreltail. Attachment 1 to this appendix presents photos of the vegetation in September 1999 and June 2002.

The high percentage of introduced species indicates past disturbance to the plant community which was due to soil excavation and disturbance during landfilling activities. Cheatgrass forms an extensive "mat" of ground cover, thus preventing the re-establishment of native perennial grasses. The SWERA indicted that a major ecological concern of the dominance of non-native annual species is that this may alter the frequency and timing of wildfires. An abundance of cheatgrass enhances the likelihood of fire spread (Bunting et al., 1987).

B.3.4.2 Re-establishment of Vegetation

A major component for each of the corrective measures alternatives evaluated in this report is the establishment of hardy vegetation. For the two alternatives which include construction of a multi-layer or ET cover, the entire cover area will require a new vegetative layer. Development of vegetation will be more difficult because of the barrier layer present beneath the 30 inches of cover soil. Therefore, the only species which can be planted are those with shallow root systems. This will limit the types of plants which can be used and will make establishment of a vegetative layer more difficult for Alternatives 1 and 2.

The third alternative, upgrading the existing cover, will require new vegetation in areas which are currently lacking sufficient cover. This alternative will also include additional soil cover over areas of surface debris and these areas will need new vegetation. Because this alternative does not have a barrier layer to prevent exposure of debris, a good vegetative layer is necessary to prevent soil erosion due to water and wind.

In general, it is preferred that the vegetative layer consist of a mix of perennial native grasses, forbs, and shrubs which grow well in arid conditions, and in slightly alkaline, sandy, gravelly soil. However, native species are often harder to establish than certain introduced species such as cheatgrass and sweetclover. The native species need more attention to take root in the Tooele Valley because of the poor soil conditions and the arid, windy environment. Therefore, introduced species tend to initially dominate disturbed areas and prevent eventual growth of native species. However, some natives such as crested wheatgrass grow well in these conditions and are known to outcomplete cheatgrass.

As stated above, the multi-layer and ET cover alternatives will only have 30 inches of soil for the roots to grow in. As many of these species have root systems that typically reach below this depth, the effect of this limiting factor must be considered and the appropriate mix of plants chosen.

Potential grasses and forbs to be planted for site restoration include those currently found at the site (listed above), those listed in Section B.3.2, and additional species such as crested, western, or slender wheatgrass (Chambers, 1989). However, some of the listed native species, while having many beneficial qualities, such as Indian ricegrass and shadscale, are generally known to be difficult to establish (Vallentine, 1971); (Bleak et al, 1965). Knowledge of local planting conditions will be vital. For example, Indian ricegrass seedlings are reported to fair better during wet springs (Plummer and Frischknecht, 1952) and may grow well in this area when rain levels peak in March and April. Wyoming big sagebrush, while useful to stabilize slopes and gullies, requires several years to establish and is more work intensive than introduced grasses (McArthur et al., 1977). Live plantings of shrubs would decrease the time for root development but the shrubs must receive enough moisture or they will die.

Due to the complexity of determining the best mix of vegetation, it is recommended that during the corrective measure design phase, a botanist or agronomist knowledgeable in local planting conditions be contacted to help develop a plant mix and seeding schedule which will allow for a fast growing vegetation cover to prevent soil erosion but will also allow for a diverse mix of grasses, forbs, and shrubs to eventually develop. The Tooele Field Office of the USDA Natural Resources Conservation Service should be contacted for information on local planting conditions. The method of seeding and maintenance provided must be determined using local knowledge of plant development. For example, for species such as crested or western wheatgrass, no-till drilling may be preferred over seeding. Spray seeding is less expensive but, in general, is less effective for establishing good seed contact with the soil. Providing for a healthy vegetation community will require years of maintenance.

B.4 MODELING

Modeling was performed to evaluate the relative performance of various landfill cover and cap designs. The Hydrologic Evaluation of Landfill Performance (HELP)[1] model calculates the amount of water (i.e. gallons per area per time) that could pass through the bottom layer of a given soil cover or multi-layered cap. The model is limited to relatively simple cases and cannot account for all of the intricacies of a given landfill design but provides data used to compare the infiltration rates for each landfill design tested, thereby evaluating their relative performance.

[1] The *Hydrogeologic Evaluation of Landfill Performance (HELP) Model*. USEPA, EPA/600/R-94/168a/ 1994.

The HELP computer program is a quasi-two-dimensional hydrologic model of water movement across, into, through and out of landfills. The model accepts weather, soil, and design data, and uses solution techniques that account for the effects of surface storage, lateral subsurface drainage, unsaturated vertical drainage, and infiltration through soil, geomembrane or composite liners. Landfill systems including various combinations of vegetation, cover soils, waste cells, lateral drainage layers, low permeability barrier soils and synthetic geomembrane liners may be modeled. The program was developed to conduct water balance analysis of landfills, soil cover and multi-layered geosynthetic cap systems, and solid waste disposal and containment facilities. As such, the model facilitates rapid estimation of the amounts of runoff, evapotranspiration, drainage, leachate collection, and barrier/liner infiltration that may be expected to result from the operation of a wide variety of landfill designs. The primary purpose of the model is to assist in the comparison of design alternatives as judged by their water balances.

This evaluation of landfill alternatives was conducted using version 3.03 of the HELP3 model. This model requires the following steps: (1) enter weather data, (2) enter soil and design data, and (3) execute simulation over a selected time frame. Weather data for TEAD was selected from a list of U.S. cities included in the model. The program contains a database of weather data for each of the available cities. Salt Lake City, Utah was the closest and most representative of the climate at TEAD. The weather database for Salt Lake City contains information such as: precipitation, temperature, solar radiation, and evapotranspiration. Soil and design data are entered for each layer of the landfill cover or cap, and include the soil/material type, layer thickness, hydraulic conductivity (permeability), slopes for the surface layer and any drainage layers, and type of surface cover (e.g. bare ground, fair stand of grass, or excellent stand of grass). The simulation can be executed for one or more years. For modeling at landfill SWMU 12/15, a period of 30 years was selected.

Two important factors for the evaluation of the infiltration rates at TEAD are the average monthly precipitation totals and mean monthly temperatures. The average annual precipitation total for Salt Lake City is 14.88 inches per year. The highest monthly average precipitation occurs between February and May. During the final quarter of the year (September to December) the average temperature falls from 78 to 30°F while precipitation totals increase gradually. Figure B-2 presents the average monthly precipitation and temperature, derived from the Salt Lake City database.

Existing Soil and Vegetative Cover

The first run of the HELP3 model was intended to simulate baseline conditions at the Landfill. The simulation was conducted assuming that two feet of native soil with a permeability of 2×10^{-3} cm/sec have been placed over the existing landfill. Figure B-3 presents the results of this baseline scenario. The mean monthly infiltration for this scenario is 0.061 inches per unit area. The percent of the total precipitation infiltrating and reaching the buried wastes is 4.92 percent.

Multi-Layer Landfill Cap

The HELP3 model was used to evaluate infiltration rates for the multi-layered geosynthetic membrane cap. Figure B-4 presents the results of this modeling. This design included seven layers: four vertical percolation layers, one lateral drainage layer, one flexible membrane liner, and a geosynthetic membrane liner. The mean monthly infiltration for this scenario is 0.0033 inches per unit area. The percent of the total precipitation infiltrating and reaching the buried wastes is 0.264 percent. Additional details about the landfill cap design are presented in the table below:

Layer Number	Layer Type	Thickness (inches)	Permeability (cm/sec)	Layer Description
1	Vertical Percolation	6	3.7E-04	Topsoil/Vegetative
2	Vertical Percolation	24	7.2E-04	Protective Soil Layer Common Borrow
3	Lateral Drainage	0.25	33	Geonet/Drainage
4	Flexible Membrane	0.04	2.0E-13	Polyethylene Geomembrane
5	Barrier	0.70	5.0E-09	Geosynthetic Clay Liner (GCL)
6	Vertical Percolation	0.25	33	Geonet/Gas Venting
7	Vertical Percolation	30	7.2E-04	Foundation Soil Layer Common Borrow

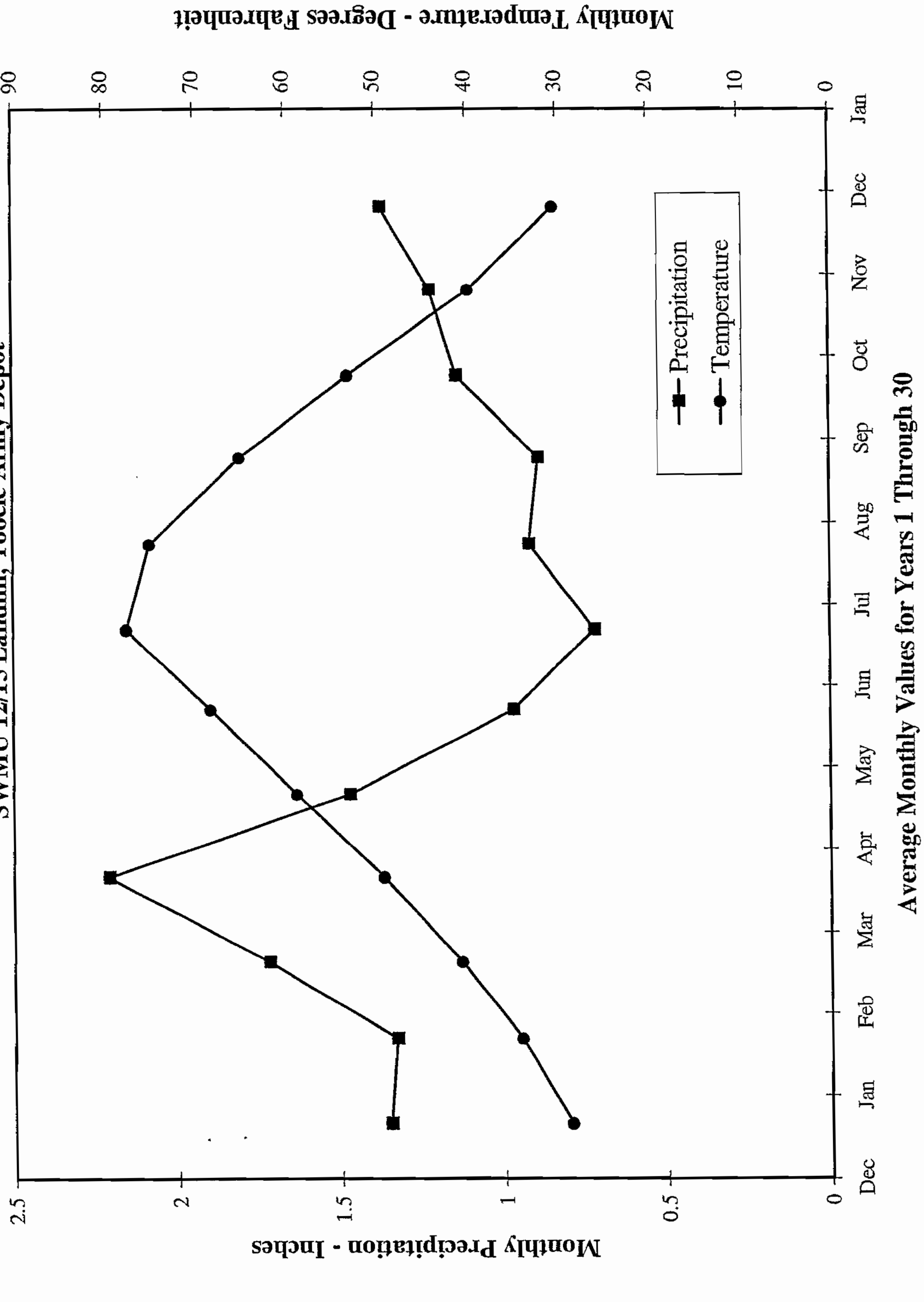
ET Landfill Cover

The HELP3 was used to evaluate infiltration rates model for a compacted and vegetated soil cover. The compacted soil acts as a barrier to reduce infiltration through the soil cover. Figure B-5 presents the results of this modeling. The compacted soil is assumed to have a permeability of 1.0E-05 cm/sec. The compacted soil is assumed to be amended with bentonite to achieve this permeability. In addition to this barrier layer, the ET cover includes three other layers: two vertical percolation layers, and a lateral drainage layer. The mean monthly infiltration for this scenario is 0.029 inches per unit area. The percent of the total precipitation infiltrating and reaching the buried wastes is 2.36 percent.

Layer Number	Layer Type	Thickness (inches)	Permeability (cm/sec)	Layer Description
1	Vertical Percolation	6	3.7E-04	Topsoil/Vegetative
2	Lateral Drainage	24	2.0E-03	Protective Soil Layer Common Borrow
3	Barrier	18	1.0E-05	Barrier Soil Layer
4	Vertical Percolation	30	2.0E-03	Foundation Soil Layer Common Borrow

The HELP model data inputs and results for the baseline, multi-layer, and ET cover scenarios are presented at the end of this appendix in Attachment 2.

Figure B-2
Monthly Precipitation and Temperature
SWMU 12/15 Landfill, Tooele Army Depot



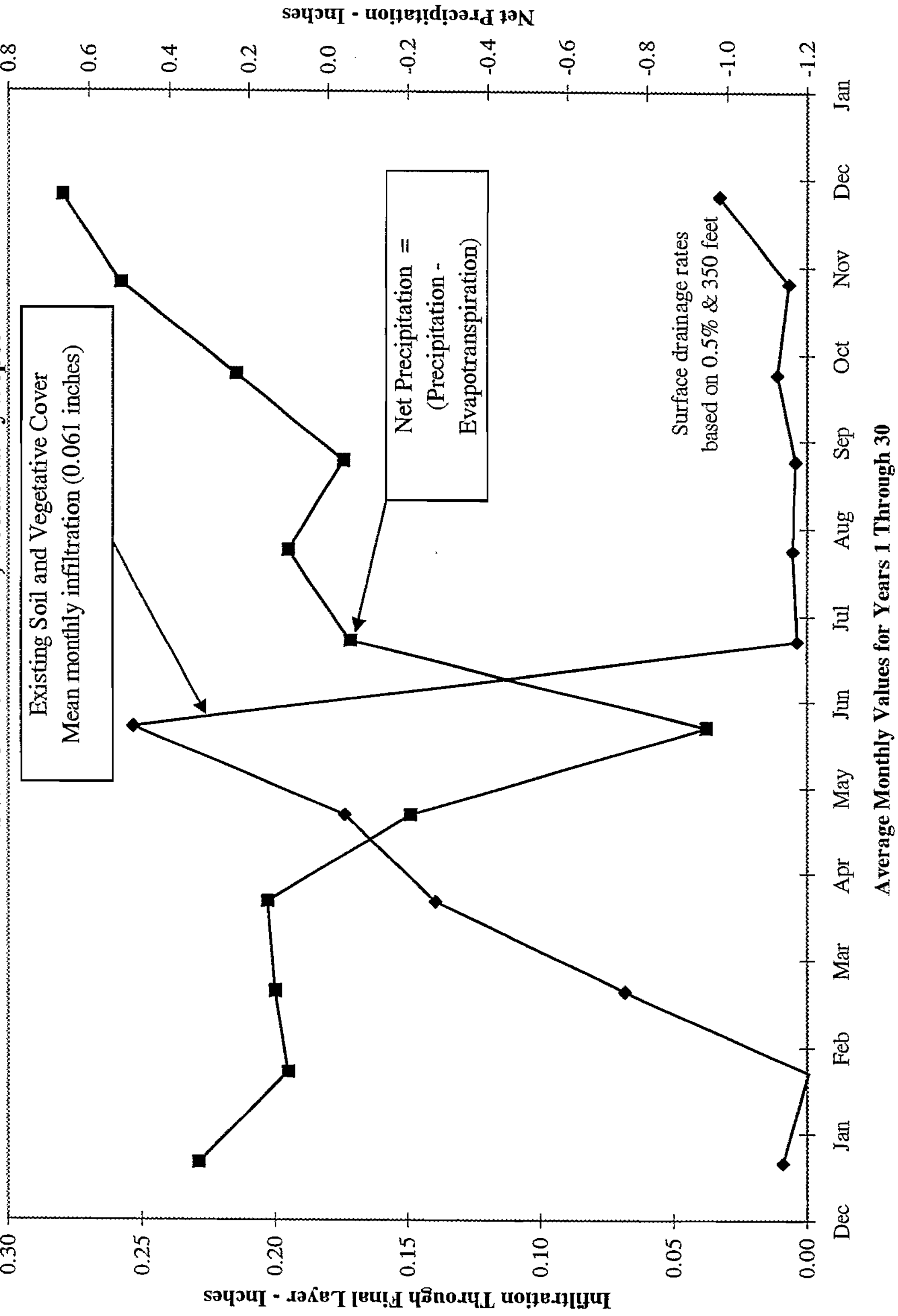


Figure B-3
Existing Soil and Vegetative Cover for CMS Report
SWMU 12\15 Landfill, Tooele Army Depot

Figure B-4
Multi-Layer Landfill Cap for CMS Report
SWMU 12\15 Landfill, Tooele Army Depot

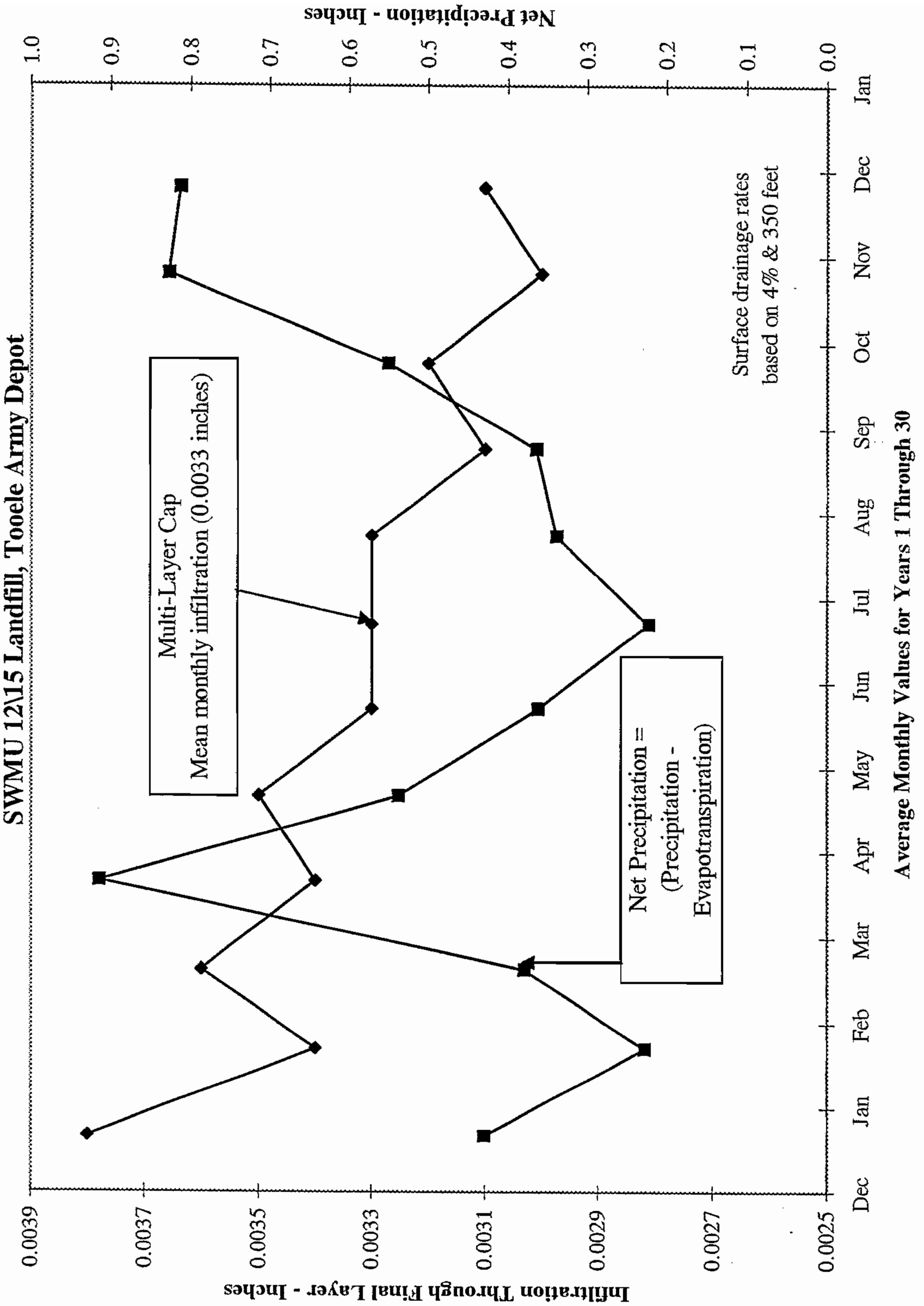
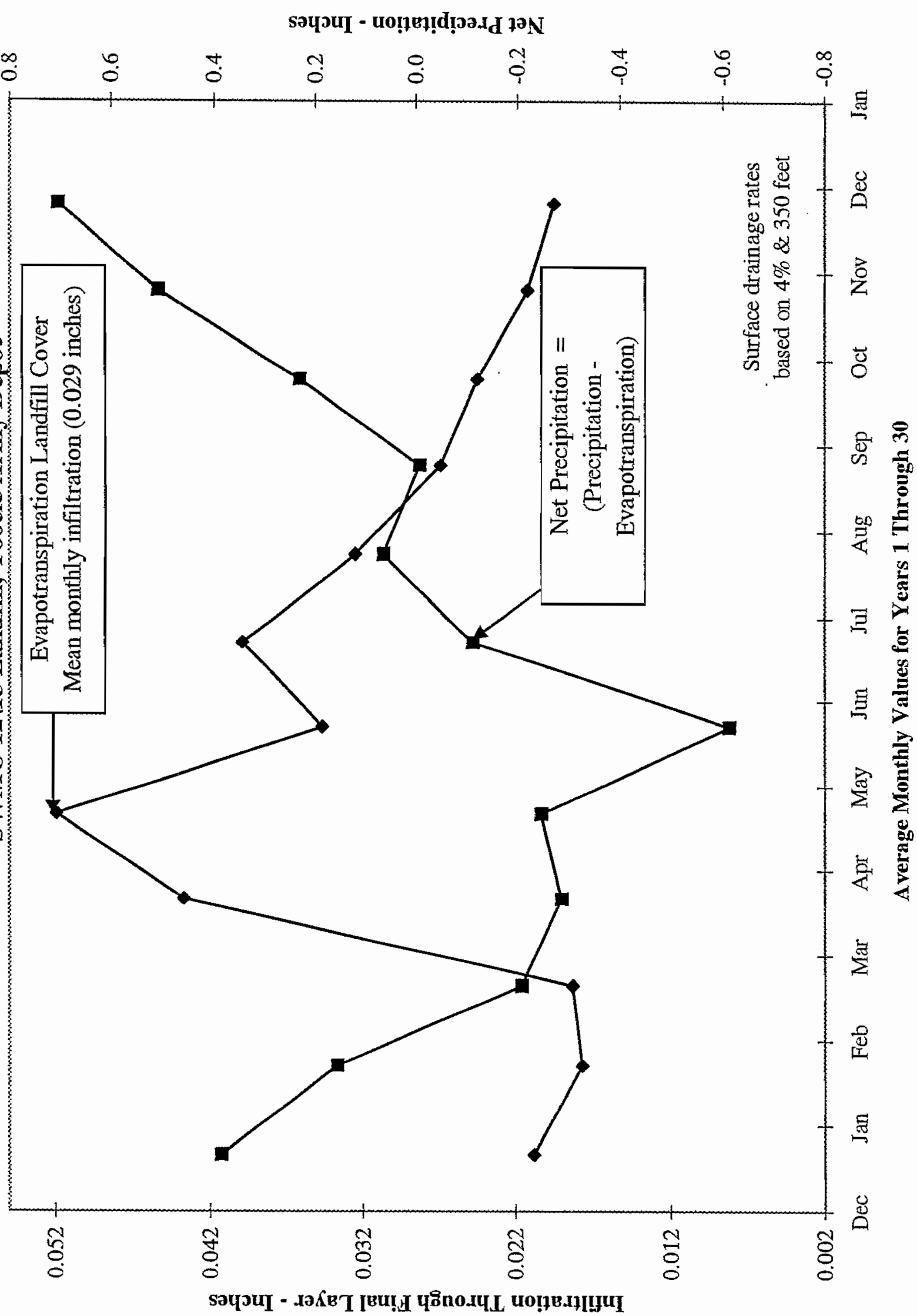


Figure B-5
Evapotranspiration Landfill Cover for the CMS Report
SWMU 12\15 Landfill, Tooele Army Depot



B.5 CONCEPTUAL DESIGN OF ALTERNATIVE COVER SYSTEMS

Capping the Sanitary Landfill/Pesticide Disposal Area involves designing and constructing a final cover to control wind dispersion of buried waste; provide long-term minimization of migration of liquids through the closed landfill; and build a stormwater management system to collect and control landfill runoff. Based on the nature of the buried waste and site conditions at the Sanitary Landfill/Pesticide Disposal Area, the following three alternative landfill covers were evaluated:

- Alternative 1 - Multi-layer landfill cap
- Alternative 2 - ET landfill cover
- Alternative 3 - Improvements to existing soil and vegetative cover

B.5.1 Alternative 1 – Multi-layer Landfill Cap

The first alternative is a multi-layer landfill cap that would meet the requirements for a RCRA Type "C" hazardous waste landfill. As discussed in Section B.1, these requirements are not applicable to SWMU 12/15.

Figure B-6 depicts the multi-layer landfill cap system for SWMU 12/15. This capping alternative involves the construction of a cover system comprised of the following layers from top to bottom:

- A 6-inch protective vegetative topsoil layer designed to minimize cap erosion and to promote drainage off the cap. The surface shall have slopes of at least 3 percent but not more than 5 percent over most of the capped area. Surface slopes of up to 33 percent occur for short distances on side slopes near the landfill perimeter;

- A 24-inch protective soil layer consisting of soil borrowed from on and off-site. This layer is designed to minimize erosion, mitigate root penetration and freeze/thaw problems, and store infiltrated water for later evaporation;

- A geosynthetic drainage layer to minimize water infiltration into the low permeability layer – composed of geotextile wrapped geonet with a nominal thickness of approximately one-quarter inch and an in-plane hydraulic transmissivity greater than 3×10^{-5} m^2/sec and a final slope of at least 2 percent after settlement. This layer is an alternative to EPA guidance for soil drainage layers;

- A double-component (barrier) low permeability liner system located below the frost zone – to provide long-term minimization of water infiltration into the underlying waste – consisting of a 40 mil thick geomembrane (GM) placed over a geosynthetic clay layer (GCL). A GCL is a factory-manufactured hydraulic barrier typically consisting of bentonite clay or other low permeability material, supported by geotextiles and/or geomembranes which are held together by needling, stitching, or chemical adhesives. For the purpose of this evaluation the GCL will consist of approximately 1 lb/ft^2 of adhesive-bonded granular sodium bentonite sandwiched between an upper primary woven geotextile and a lower secondary open weave geotextile. The installed GCL is assumed to the following properties: a hydraulic conductivity (k) of 5×10^{-9} cm/s; a thickness of 0.7 inches; and a final slope of at least 3 percent after settlement;

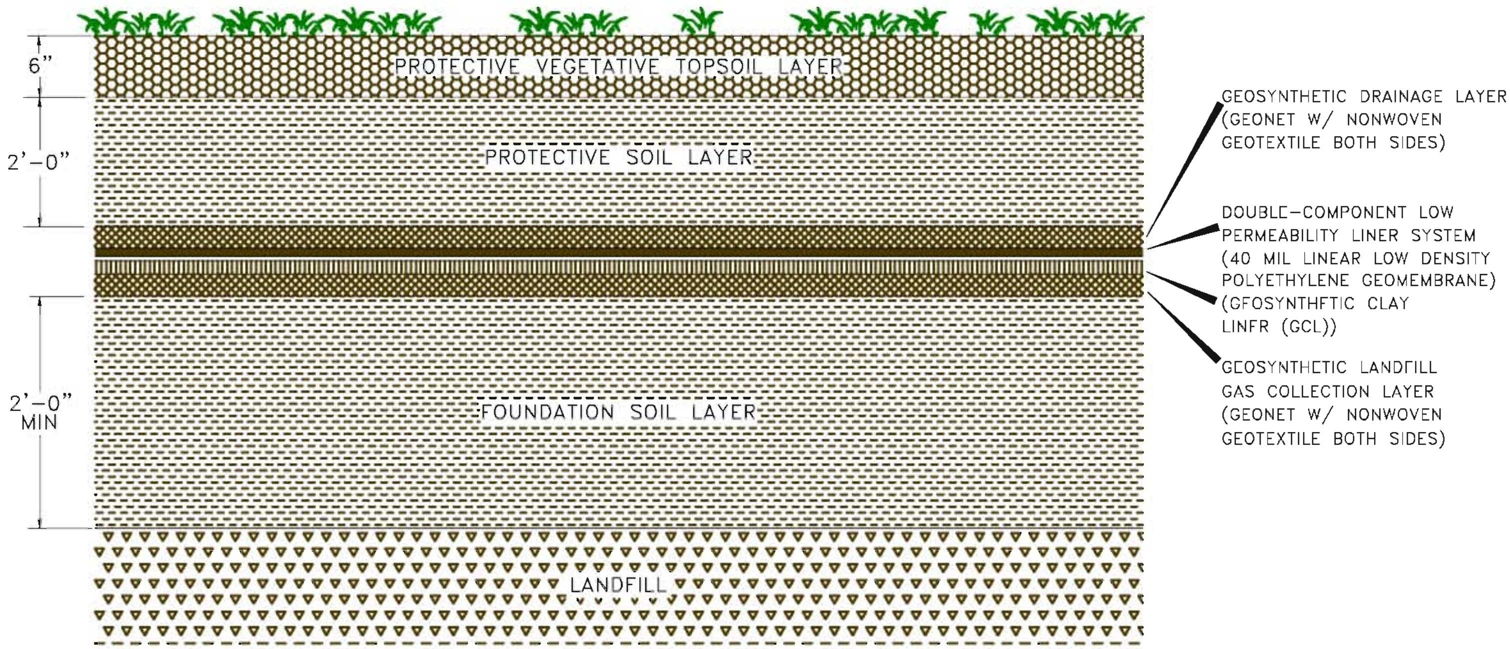
- A geosynthetic landfill gas collection layer to remove soil gases. This layer also consist of geotextile wrapped geonet (see drainage layer description above). The methane will be vented from extraction wells and passive wells;

- A foundation soil layer that is the structural base for the final cover. It includes the soils that cover the buried waste and any additional regrading required to prepare the landfill for construction of the final cover (i.e., smoothing out high relief). Based on the topography and the thickness of buried waste at SWMU 12/15, it is estimated that approximately 600,000 cubic yards of foundation layer soil fill will be required over the limit of the landfill in order to maintain the minimum slope requirement of 3 percent for the cap and to reduce the potential for damage from settlement and subsidence.

Also included in the landfill cover is a stormwater management system to control runoff from rainfall and snowmelt. A large portion of the landfill cap run off will flow into the existing arroyo which will be stabilized to prevent infiltration of stormwater, landfill runoff to buried waste, and cap erosion. A stabilized channel of soil-cement cover will channel runoff from the cap to a stable outlet where it can evaporate or flow beyond the cap (see Figure B-7). This channel will also serve as a structural reinforcing element for the landfill cover on the adjacent hill slopes. The channel is to provide hydraulic capacity for stormwater flow. An additional benefit will be the use of the channel for vehicle access to the interior of the landfill for inspection and maintenance.

A soil-cement channel was selected over the other potential options (asphalt channel and extension of the cap to cover the channel) on the basis of durability, reliability, performance, implementability, and cost. However, the application of a low permeability, low maintenance modified asphalt cover should be investigated as an alternative during the design phase.

The historical extent of the landfill is approximately 70 acres. This entire area will be capped with all of the components discussed above (see Figure B-8). To be conservative and account for the irregular shape of the landfill, a total of 90 acres is assumed to be capped. An additional 30 acres is estimated to be necessary around the cap perimeter to provide a uniform but not excessively steep surface grade from the cap to the surrounding existing ground surface. This additional cover area is assumed not to require the geosynthetic drainage layer, the double-component low permeability liner or the geosynthetic landfill gas collection layer.

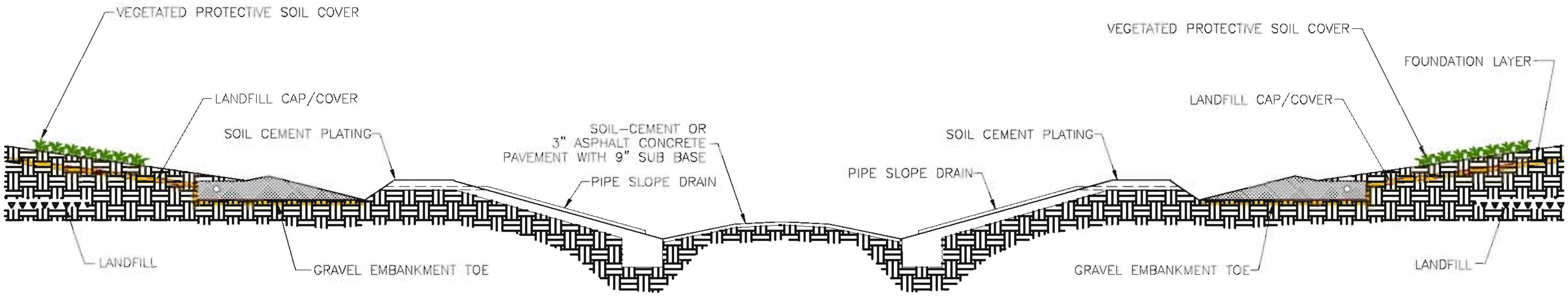


NOT TO SCALE

NOTE: FOUNDATION SOIL LAYER MAY INCLUDE EXISTING COVER LAYER.

FIGURE B-6
MULTI-LAYER LANDFILL CAP
CROSS SECTION (TYPICAL)
SANITARY LANDFILL AND
PESTICIDE DISPOSAL AREA (SWMU 12/15)
TOOELE ARMY DEPOT

URS



NOT TO SCALE

FIGURE B-7
STABILIZED CHANNEL/LANDFILL SECTION
SANITARY LANDFILL AND
PESTICIDE DISPOSAL AREA (SWMU 12/15)
TOOELE ARMY DEPOT

URS

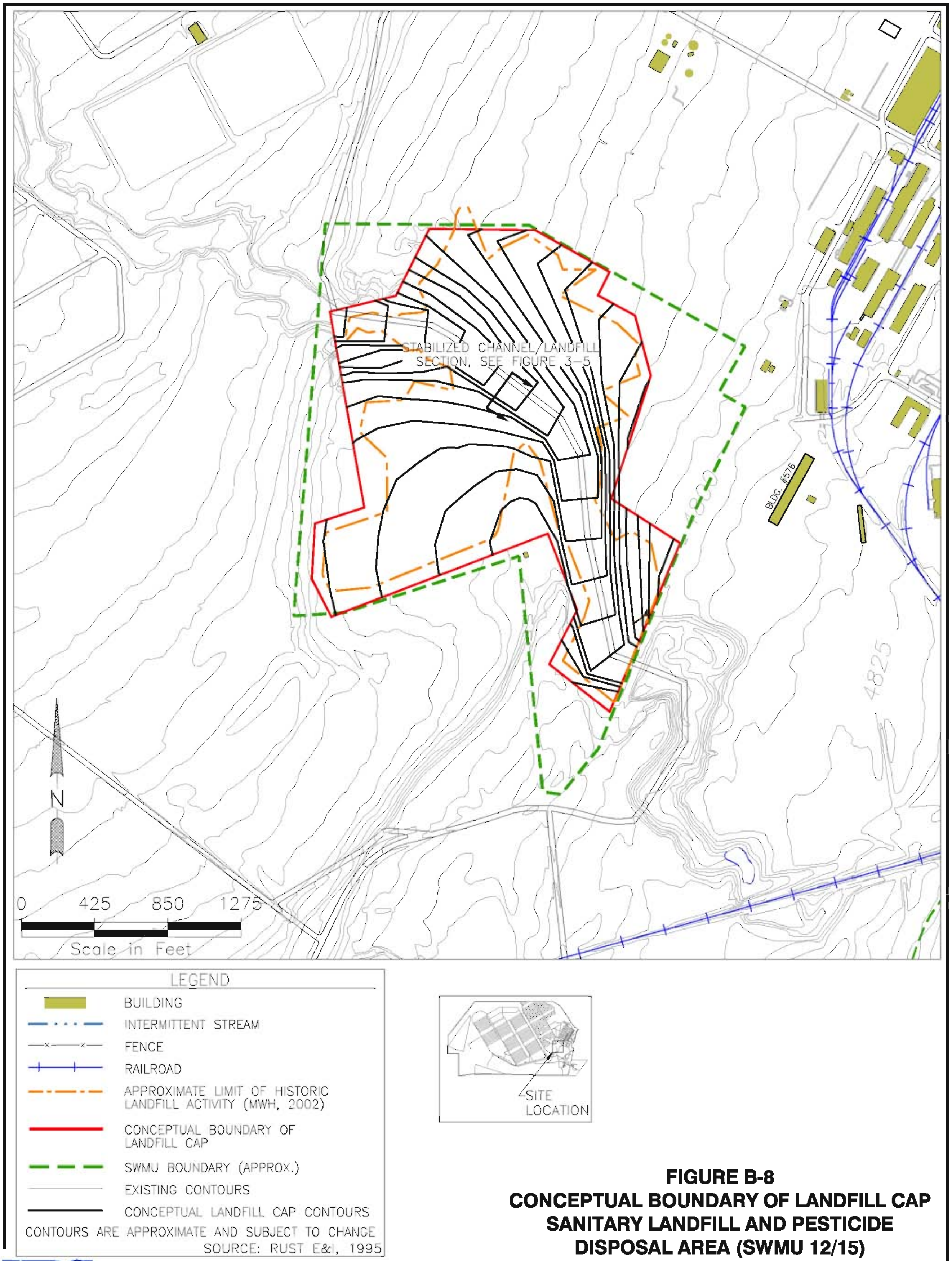


FIGURE B-8
CONCEPTUAL BOUNDARY OF LANDFILL CAP
SANITARY LANDFILL AND PESTICIDE
DISPOSAL AREA (SWMU 12/15)
TOOELE ARMY DEPOT

URS

Provisions for inspection and maintenance of the cover system are also included in this alternative.

Inspections and maintenance are required to ensure the long-term effectiveness of the multi-layer cover system. The physical properties of GCLs are subject to extensive quality assurance/quality control at the manufacturing location which results in a uniform and highly dependable material. GCLs are typically easy to install. The arid climate at TEAD could potentially effect the long term performance of the GCL. Moreover, the permeability of GCLs can be adversely impacted by out of plane deformations caused by moderate differential settlement in the cover system. Nevertheless, GCLs have been used in many landfill cover systems with positive results and the long-term reliability of the GCL is not likely to decrease with time.

<u>Alternative Landfill Layer Components</u>

An evaluation of different drainage and barrier layers was conducted as part of the conceptual design of the multi-layer cap. Presented below are several alternative drainage and barrier layers with a discussion of why they were not chosen for the conceptual design.

An alternative to the geosynthetic drainage and landfill gas collection layers are drainage and gas collection layers comprised of 12-inches of poorly graded gravels (or a gravel sand mixture) with a minimum hydraulic conductivity of 1×10^{-2} cm/sec and a final slope of at least 3 percent after settlement. The geosynthetic layers were chosen over 12-inches of gravel/sand because the cost for the geosynthetic layer is less. Also, the geosynthetic layers are less than one inch thick, each resulting in an overall cap thickness reduction of 22 inches compared to using the 12-inch gravel/sand layers. Minimizing the cap thickness reduces the area of the cap protective cover layer needed beyond the landfill boundary (because less soil is necessary around the cap perimeter to provide a uniform but not overly steep surface grade from the cap surface to the surrounding existing ground surface).

An alternative to the selected GM/GCL barrier liner is a single-component low permeability liner system to also provide long-term minimization of water infiltration into the underlying waste – consisting of a 60-mil geomembrane placed over 24-inches of moderate density soils with a maximum hydraulic conductivity of 1×10^{-5} cm/sec and a final slope of at least 3 percent after settlement (GM/soil barrier). The GM/GCL barrier is chosen over the GM/soil barrier because the GM/soil barrier is more expensive and susceptible to puncture damage during construction. The GM/soil barrier is expected to allow equal or more infiltration through the landfill than the GM/GCL barrier. Also the GM/GCL barrier is less thick than the GM/soil barrier which reduces the cap protective cover layer area as discussed above.

A second alternative to the selected GM/GCL barrier liner is a double-component low permeability liner system to provide long-term minimization of water infiltration into the underlying waste – consisting of a 40 mil geomembrane placed over 24-inches of high density compacted clay (CC) with a maximum hydraulic conductivity of 1×10^{-7} cm/sec and a final slope of at least 3 percent after settlement (GM/CC barrier). The GM/GCL barrier is chosen over the GM/CC barrier because the GM/CC barrier is more expensive and susceptible to desiccation under the arid conditions at the site. Discontinuities in the compacted clay layer resulting from differential settlement may further compromise the reliability of the cap by providing preferential pathways for percolation through the cover system. The GM/CC barrier is expected to allow equal or slightly more infiltration through the landfill than the GM/GCL barrier. Also the GM/GCL barrier is less thick than the GM/soil barrier which reduces the cap protective cover layer area as discussed above.

B.5.2 Alternative 2 – Evapotranspiration (ET) Landfill Cover

The second alternative is an evapotranspiration (ET) landfill cover. This landfill cap is constructed to meet the requirements of the State of Utah regulations for sanitary landfill closure {UAC R315-303-3(4) (Landfilling Standards)}. As discussed in Section B.1, these regulations do not apply to SWMU 12/15. These regulations would require that the landfill cover must have a permeability of 1×10^{-5} cm/sec or less and the landfill cover must have a permeability less than or equal to the permeability of any bottom liner system or natural soils present. However, the Executive Secretary may approve an alternative final cover design if the infiltration layer achieves an equivalent reduction in infiltration compared to an infiltration layer achieving a permeability of 1×10^{-5} cm/sec or less. Initially the ET landfill cover will most likely allow more infiltration than the multi-layer cap but over the long term should have fewer problems with cracking which results in significant infiltration and maintenance costs. Figure B-9 depicts the ET landfill cover system for SWMU 12/15. This capping alternative involves the construction of a cover system comprised of the following from top to bottom:

- A 6-inch protective vegetated topsoil layer designed to minimize cap erosion and to promote drainage off the cap. The surface shall have slopes of at least 3 percent but not more than 5 percent over most of the capped area. Surface slopes of up to 33 percent occur for short distances on side slopes near the landfill perimeter.

- A 24-inch protective soil layer consisting of soil borrowed from on and off-site. This layer is designed to minimize erosion, mitigate root penetration and freeze/thaw problems, and store infiltrated water for later evaporation. Based on a frost depth of 21 to 24-inches, approximately 6 to 9 inches or more of this soil cover will be available year-round for lateral drainage of water. Although 1 foot of drainage soil below the frost line is typical for this application, HELP model simulations indicate 9 inches of drainage soils below the frost line are sufficient.

NOT TO SCALE

NOTE: FOUNDATION SOIL LAYER MAY INCLUDE EXISTING COVER LAYER.

FIGURE B-9
EVAPOTRANSPIRATION LANDFILL COVER CROSS SECTION (TYPICAL)
SANITARY LANDFILL AND
PESTICIDE DISPOSAL AREA (SWMU 12/15)
TOOELE ARMY DEPOT

URS

- An 18-inch barrier soil layer that provides long-term minimization of water filtration into the underlying landfill. It will be comprised of compacted local borrow soils amended with bentonite or other material if necessary to achieve a permeability of at least 1×10^{-5} cm/sec after placement and compaction.

- A foundation soil layer which serves as the structural base for the final cover. It includes the daily and intermediate soils which cover the buried waste and any additional regrading required to prepare the landfill for construction of the final cover (i.e., smoothing out high relief). Based on the topography and the thickness of buried waste at SWMU 12/15 it is estimated that approximately 600,000 cubic yd^3 of foundation layer soil fill will be required over the limit of the landfill in order to maintain the minimum slope requirement of 3 percent for the cap and to reduce the potential for damage from settlement and subsidence.

Also included in the landfill cover is a stormwater management system to control runoff from rainfall and snowmelt. A large portion of the landfill cap run off will flow into the existing arroyo which will be stabilized to prevent infiltration of stormwater, landfill runoff to buried waste, and cap erosion. A stabilized channel of soil-cement cover will channel runoff from the cap to a stable outlet where it can evaporate or flow beyond the cap (see Figure B-7). This channel will also serve as a structural reinforcing element for the landfill cover on the adjacent hill slopes. The channel is to provide hydraulic capacity for stormwater flow. An additional benefit will be the use of the channel for vehicle access to the interior of the landfill for inspection and maintenance.

The historical extent of the landfill is approximately 70 acres. This entire area will be capped with all of the components discussed above (see Figure B-8). To be conservative and account for the irregular shape of the landfill, a total of 90 acres is assumed to be capped. An additional 30 acres is estimated to be necessary around the cap perimeter to provide a uniform but not excessively steep surface grade from the cap to the surrounding existing ground surface. This additional cover area is assumed not to require the barrier soil layer.

A soil-cement channel was selected over the other potential options (asphalt channel and extension of the cap to cover the channel) on the basis of durability, reliability, performance, implementability, and cost. However, the application of a low permeability, low maintenance modified asphalt cover should be investigated as an alternative during the design phase.

Provisions for inspection and maintenance of the cover system are also included in this alternative.

Inspection and maintenance is required to ensure the long-term effectiveness of the soil cover system.

B.5.3 ALTERNATIVE 3 - IMPROVE EXISTING SOIL AND VEGETATIVE COVER

The third alternative consists of improving the existing soil cover. Currently the landfill cover consists of soil with vegetation. Section B.3 of this appendix presents a preliminary evaluation of the existing landfill cover. This section presents a list of potential activities for improving the existing soil cover to ensure the CAOs for SWMU 12/15 are met currently and in the future. This includes prevention of debris exposure due to soil erosion by wind or water.

During the design phase for this corrective measure, a detailed evaluation of the condition of the existing soil cover would be performed. Objectives of the evaluation include identifying all areas of surface debris, the types and abundance of vegetation cover, and the potential of soil erosion due to precipitation and stormwater runoff. Soil erosion is typically due to high wind and stormwater runoff velocities and flow rates, poor vegetation, steep and/or unstable bank slopes, and poor soil bearing capacity.

Below are preliminary recommendations for upgrading the soil cover. The detailed evaluation described above will be necessary to verify and substantiate these assumptions in this report and develop an engineering design.

B.5.3.1 Potential soil erosion due to precipitation

As discussed in Section B.3, the majority of the landfill terrain is gently sloping (i.e., 3 to 8 %) and covered with vegetation. Much of the arroyo has steep banks with slopes ranging from approximately 16% to 100% with the majority of the slopes equaling roughly 30%.

The northern portion of the landfill generally slopes towards the arroyo. Areas within the southern portion of the landfill are rougher with many small changes in topography. Most of the stormwater runoff in these areas flows into a low point within their own areas. Section B.4 discusses precipitation and soil infiltration conditions for the landfill soil cover.

The north and northeastern slopes of the arroyo receive the greatest potential upgradient stormwater runoff. These areas are slightly sloped (approximately 1 to 8 %) and most areas appear to have good vegetation coverage. Therefore, regrading to decrease the slope is not recommended for these areas. Some of the southern slopes of the arroyo have a much steeper slope but have a very small upgradient drainage area. These slopes are mostly covered with cobbles and shrubs. At this time, regrading of the arroyo sides to allow for a gentler slope does not seem necessary. The cobble and shrub cover appears to protect these slopes from soil erosion. The arroyo has vegetation except for the access road running along its base. This access road consists of a hardpan gravelly cover which is not expected to have significant erosion to due storm water runoff. However, the condition of the existing access road and the need for additional access roads will be evaluated during the design phase and the roads upgraded as necessary.

Potentially unstable soil can be repaired in several ways. Steep bank slopes can be excavated and regraded to achieve a smaller slope. However, the potential presence of landfilled material, especially armaments, and partially filled drums limits the practice of extensive excavation at SWMU 12/15. Soil erosion control mats can be used to stabilize soil until vegetation can take hold. Diversion ditches can be constructed to intercept precipitation runoff and divert it away from vulnerable areas. In areas that are either very steep or have significant water erosion, structural methods such as riprap revetments and gabion walls may be also utilized. The existing cobble cover on the steeper arroyo banks was probably placed there to prevent soil erosion.

To summarize, the preliminary evaluation for the landfill topography suggests that there are no major areas of imminent exposure of buried wastes due to erosion. It should be noted that the exact soil cover thickness is unknown over much of the landfill. Another uncertainty is the long term settlement of materials, some of which was buried in the general area of the arroyo as recently as the mid 1980s. Areas with a very small amount of cover and/or future settlement could have cracks in the surface or future debris exposure. However, based on current data, major regrading changes to the current soil cover does not seem necessary to provide a stable soil cover. The design phase site survey may show that some areas need vegetation to provide for erosion prevention. Certain areas of the landfill, (i.e., arroyo banks) would benefit from additional shrubs or other species with extensive root systems. Periodic site inspections (or after major precipitation events) should be conducted to observe for soil erosion, especially in areas identified as having the potential for exposed debris due to erosion. A landfill cover maintenance plan (see Section B.5.3.5) should be developed to provide guidance for the inspecting and maintaining the soil cover.

B.5.3.2 Potential Ponding of Precipitation

As discussed in Section B.3, a preliminary estimate of the drainage areas for the landfill was performed based on the topographic survey map. The northern portion of the landfill drains into the arroyo. The southeast and west-central parts of the landfill have a very uneven topography with many shallow depressions where stormwater runoff might collect. A potential concern at low points of large drainage areas is the possibility of significant ponding of water after storm events. As discussed in Section B.4, the HELP model predicted that a two foot vegetative native soil cover allowed 4.92 percent of the total precipitation to infiltrate and reach buried wastes. This corresponds to a mean monthly infiltration of 0.061 inches per unit area.

The majority of the self contained drainage areas are less than 10 acres and are only slightly depressed from the surrounding land. Therefore, it appears that potential for significant water ponding at their low points is small. For these drainage areas, site grading is not recommended to alter current flow patterns. However, two slight depressions in a narrow segment of the western arroyo (see Figure B-1) are possible locations of significant water ponding due to the relatively large amount of upstream drainage area. It is recommended that these areas be regraded to promote better drainage.

The amount of soil excavation and fill necessary to regrade the area and prevent ponding is estimated to be approximately 800 cubic yards and 1,000 cubic yards, respectively.

It is also recommend that the drainage area in the southeast leg of the landfill (see Figure B-1 be regraded to prevent ponding due to its relatively large drainage area (10 acres), steep slopes, and the potential presence of buried wastes. The goal of regrading would be to allow precipitation runoff from this area to drain into the arroyo. Regrading would consist of adding soil to the deepest part of the depression and excavating portions of the surrounding hillside to provide an outlet for the runoff to reach the arroyo. The amount of soil fill and soil excavation necessary is estimated to be approximately 10,300 and 1,000 cubic yards, respectively. It is assumed UXO screening will be required for excavated areas.

B.5.3.3 Surface Debris

A preliminary evaluation of surface debris at the landfill is presented in Section B.3. Under this alternative, exposed debris will be covered with a vegetative soil layer. To minimize the amount of new soil cover and vegetation necessary, when possible, surface debris will be collected, centralized, and covered. For cost estimating purposes it is assumed that the area of exposed surface debris can be cut by half through collection and centralizing of rubble and debris. One potential area where debris could be centralized and covered is the depression in the southeast leg of the landfill where regrading is recommended (see Section B.5.3.2). The soil cover will consist of 2 feet of native soil, 3 inches of topsoil and vegetation. The cover is assumed to mimic the existing site topography with the exception of steeper slopes along cover perimeters.

B.5.3.4 Vegetation

Areas with poor vegetative coverage may need additional seed bed preparation and seeding to provide increased vegetation and soil stabilization. For cost estimating purposes it is estimated that approximately 30 acres will require seeding. This includes areas to receive additional soil cover as described above. It is assumed topsoil will be required for some areas. Types of species for re-establishment of vegetation are discussed in Section B.3. Temporary soil erosion controls and protective measures for the vegetation such as mulch and soil erosion control mats may be utilized.

B.5.3.5 Maintenance Plan

A landfill cover maintenance plan should be developed to provide guidance for inspecting and maintaining the cover. As part of the maintenance plan, a vegetation plan will be developed and implemented to ensure a strong vegetative layer throughout the landfill cover. Periodic site inspections should be conducted to observe for soil erosion, especially in areas identified as having the potential for exposed debris due to erosion. Attachment 1 of the TEAD Post-Closure Permit is the *Post-Closure Monitoring, Maintenance, and Inspection of the Industrial Waste Lagoon (IWL), Associated Wastewater Collection Ditches, and Groundwater Treatment System*. This attachment addresses the inspection and maintenance activities for the cover at the IWL and provides a useful example of requirements to be included in the maintenance plan for the soil cover at SWMU 12/15.

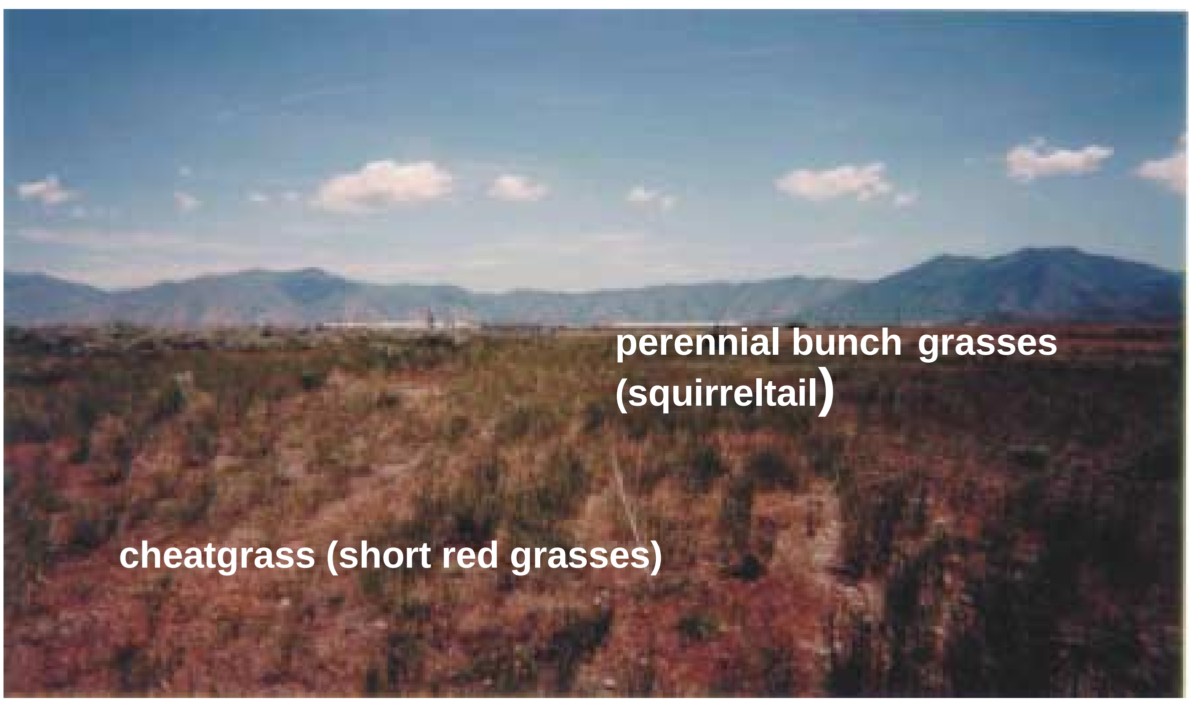
ATTACHMENT 1

SWMU 12/15 Plant Photos

SWMU 12/15: View of north central-northwest area of landfill (June 5, 2002)

SWMU 12/15: View looking southeast from northwest corner of landfill towards arroyo (Sept. 20, 1999)

SWMU 12/15: View looking west from eastern border of landfill (Sept. 20, 1999)



SWMU 12/15: View looking east/northeast from southwest corner of landfill (June 5, 2002)

ATTACHMENT 2

HELP Model Results for SWMU 12/15

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.03  (31 DECEMBER 1994)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
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TEMPERATURE DATA FILE:      C:\HELP3\data7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\data13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\data11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\nocap.D10
OUTPUT DATA FILE:           C:\HELP3\nocap.OUT

TIME:  15:28     DATE:  12/ 9/1998


******************************************************************************

    TITLE: Existing Soil and Vegetative(1-layer, 140 ac, 0.5% 350 ft)SWMU
12/15

******************************************************************************

     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   4
           THICKNESS                  =     24.00   INCHES
           POROSITY                   =      0.4370 VOL/VOL
           FIELD CAPACITY             =      0.1050 VOL/VOL
           WILTING POINT              =      0.0470 VOL/VOL
           INITIAL SOIL WATER CONTENT  =???????????? VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.170000002000E-02 CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  2.49
                  FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
                   GENERAL DESIGN AND EVAPORATIVE ZONE DATA
                   ----------------------------------------

         NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
                  SOIL DATA BASE USING SOIL TEXTURE # 4 WITH A
                  FAIR STAND OF GRASS, A SURFACE SLOPE OF  1.%
                  AND A SLOPE LENGTH OF  350. FEET.
```

```
SCS RUNOFF CURVE NUMBER              =     56.10
FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =    140.000  ACRES
EVAPORATIVE ZONE DEPTH               =     24.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =      1.952  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =     10.488  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =      1.128  INCHES
INITIAL SNOW WATER                   =      0.175  INCHES
INITIAL WATER IN LAYER MATERIALS     =???????????  INCHES
TOTAL INITIAL WATER                  =???????????  INCHES
TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

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NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         Salt Lake City        Utah

     MAXIMUM LEAF AREA INDEX                 =  1.60
     START OF GROWING SEASON (JULIAN DATE)  =   117
     END OF GROWING SEASON (JULIAN DATE)    =   289
     AVERAGE ANNUAL WIND SPEED               =  8.80 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY  = 67.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY  = 48.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY  = 39.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY  = 65.00 %

NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR     SALT LAKE CITY      UTAH
```

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.35	1.33	1.72	2.21	1.47	0.97
0.72	0.92	0.89	1.14	1.22	1.37

```
NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR     SALT LAKE CITY      UTAH
```

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.60	34.10	40.70	49.20	58.80	68.30
77.50	74.90	65.00	53.00	39.70	30.30

```
NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR     SALT LAKE CITY      UTAH

              STATION LATITUDE  = 40.76 DEGREES
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ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	12.09	6144138.500	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	11.952	6074164.500	98.86
PERC./LEAKAGE THROUGH LAYER 1	0.162077	82367.719	1.34
CHANGE IN WATER STORAGE	-0.024	-12392.142	-0.20
SOIL WATER AT START OF YEAR	1.952	991832.250	
SOIL WATER AT END OF YEAR	1.927	979440.125	
SNOW WATER AT START OF YEAR	0.175	88898.516	1.45
SNOW WATER AT END OF YEAR	0.175	88898.516	1.45
ANNUAL WATER BUDGET BALANCE	0.0000	-1.727	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	15.65	7953330.500	100.00
RUNOFF	0.142	72151.266	0.91
EVAPOTRANSPIRATION	15.247	7748461.500	97.42
PERC./LEAKAGE THROUGH LAYER 1	0.571682	290528.625	3.65
CHANGE IN WATER STORAGE	-0.311	-157813.078	-1.98
SOIL WATER AT START OF YEAR	1.927	979440.125	
SOIL WATER AT END OF YEAR	1.792	910525.500	
SNOW WATER AT START OF YEAR	0.175	88898.516	1.12
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	2.181	0.00

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	10.33	5249706.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	9.750	4954860.500	94.38
PERC./LEAKAGE THROUGH LAYER 1	0.157415	79998.281	1.52
CHANGE IN WATER STORAGE	0.423	214847.578	4.09
SOIL WATER AT START OF YEAR	1.792	910525.500	
SOIL WATER AT END OF YEAR	1.269	644843.625	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.946	480529.500	9.15
ANNUAL WATER BUDGET BALANCE	0.0000	-0.235	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	18.28	9289896.000	100.00
RUNOFF	0.597	303253.156	3.26
EVAPOTRANSPIRATION	15.749	8003421.000	86.15
PERC./LEAKAGE THROUGH LAYER 1	1.902612	966907.625	10.41
CHANGE IN WATER STORAGE	0.032	16313.371	0.18
SOIL WATER AT START OF YEAR	1.269	644843.625	
SOIL WATER AT END OF YEAR	2.201	1118514.120	
SNOW WATER AT START OF YEAR	0.946	480529.500	5.17
SNOW WATER AT END OF YEAR	0.046	23172.334	0.25
ANNUAL WATER BUDGET BALANCE	0.0000	1.090	0.00

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ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	12.76	6484631.500	100.00
RUNOFF	0.071	35847.641	0.55
EVAPOTRANSPIRATION	12.613	6409794.000	98.85
PERC./LEAKAGE THROUGH LAYER 1	0.634946	322679.437	4.98
CHANGE IN WATER STORAGE	-0.558	-283689.094	-4.37
SOIL WATER AT START OF YEAR	2.201	1118514.120	
SOIL WATER AT END OF YEAR	1.688	857997.375	
SNOW WATER AT START OF YEAR	0.046	23172.334	0.36
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.606	0.00

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ANNUAL TOTALS FOR YEAR 6

	INCHES	CU. FEET	PERCENT
PRECIPITATION	17.91	9101860.000	100.00
RUNOFF	0.119	60304.234	0.66
EVAPOTRANSPIRATION	15.858	8059169.500	88.54
PERC./LEAKAGE THROUGH LAYER 1	0.832280	422964.469	4.65
CHANGE IN WATER STORAGE	1.101	559422.312	6.15
SOIL WATER AT START OF YEAR	1.688	857997.375	
SOIL WATER AT END OF YEAR	2.789	1417419.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.027	13673.017	0.15
ANNUAL WATER BUDGET BALANCE	0.0000	-0.818	0.00

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ANNUAL TOTALS FOR YEAR 7

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.95	7597591.000	100.00
RUNOFF	0.017	8598.360	0.11
EVAPOTRANSPIRATION	15.651	7953586.000	104.69
PERC./LEAKAGE THROUGH LAYER 1	0.162818	82743.945	1.09
CHANGE IN WATER STORAGE	-0.907	-461008.781	-6.07
SOIL WATER AT START OF YEAR	2.789	1417419.750	
SOIL WATER AT END OF YEAR	1.362	691931.312	
SNOW WATER AT START OF YEAR	0.027	13673.017	0.18
SNOW WATER AT END OF YEAR	0.547	278152.656	3.66
ANNUAL WATER BUDGET BALANCE	0.0269	13671.130	0.18

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ANNUAL TOTALS FOR YEAR 8

	INCHES	CU. FEET	PERCENT
PRECIPITATION	12.22	6210204.000	100.00
RUNOFF	0.053	26748.926	0.43
EVAPOTRANSPIRATION	11.456	5822158.000	93.75
PERC./LEAKAGE THROUGH LAYER 1	0.282819	143728.750	2.31
CHANGE IN WATER STORAGE	0.428	217567.719	3.50
SOIL WATER AT START OF YEAR	1.362	691931.312	
SOIL WATER AT END OF YEAR	2.214	1125281.620	
SNOW WATER AT START OF YEAR	0.547	278152.656	4.48
SNOW WATER AT END OF YEAR	0.123	62370.070	1.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.788	0.00

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ANNUAL TOTALS FOR YEAR 9

	INCHES	CU. FEET	PERCENT
PRECIPITATION	17.05	8664811.000	100.00
RUNOFF	0.717	364554.719	4.21
EVAPOTRANSPIRATION	15.504	7879164.000	90.93
PERC./LEAKAGE THROUGH LAYER 1	1.516985	770931.875	8.90
CHANGE IN WATER STORAGE	-0.688	-349841.250	-4.04
SOIL WATER AT START OF YEAR	2.214	1125281.620	
SOIL WATER AT END OF YEAR	1.649	837810.437	
SNOW WATER AT START OF YEAR	0.123	62370.070	0.72
SNOW WATER AT END OF YEAR	0.018	9212.187	0.11
ANNUAL WATER BUDGET BALANCE	0.0000	1.090	0.00

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ANNUAL TOTALS FOR YEAR 10

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.16	7196113.000	100.00
RUNOFF	0.272	138164.484	1.92
EVAPOTRANSPIRATION	13.384	6801663.500	94.52
PERC./LEAKAGE THROUGH LAYER 1	0.087093	44260.844	0.62
CHANGE IN WATER STORAGE	0.399	202812.531	2.82
SOIL WATER AT START OF YEAR	1.649	837810.437	
SOIL WATER AT END OF YEAR	2.066	1049835.120	
SNOW WATER AT START OF YEAR	0.018	9212.187	0.13
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0181	9211.627	0.13

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ANNUAL TOTALS FOR YEAR 11

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.61	8441203.000	100.00
RUNOFF	0.027	13554.180	0.16
EVAPOTRANSPIRATION	15.576	7915562.000	93.77
PERC./LEAKAGE THROUGH LAYER 1	0.644370	327468.687	3.88
CHANGE IN WATER STORAGE	0.363	184617.469	2.19
SOIL WATER AT START OF YEAR	2.066	1049835.120	
SOIL WATER AT END OF YEAR	2.376	1207659.870	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.053	26792.830	0.32
ANNUAL WATER BUDGET BALANCE	0.0000	1.000	0.00

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ANNUAL TOTALS FOR YEAR 12

	INCHES	CU. FEET	PERCENT
PRECIPITATION	13.10	6657419.500	100.00
RUNOFF	0.149	75633.172	1.14
EVAPOTRANSPIRATION	13.308	6763115.000	101.59
PERC./LEAKAGE THROUGH LAYER 1	0.412345	209553.609	3.15
CHANGE IN WATER STORAGE	-0.769	-390882.969	-5.87
SOIL WATER AT START OF YEAR	2.376	1207659.870	
SOIL WATER AT END OF YEAR	1.484	754053.375	
SNOW WATER AT START OF YEAR	0.053	26792.830	0.40
SNOW WATER AT END OF YEAR	0.176	89516.305	1.34
ANNUAL WATER BUDGET BALANCE	0.0000	0.682	0.00

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ANNUAL TOTALS FOR YEAR 13

	INCHES	CU. FEET	PERCENT
PRECIPITATION	13.47	6845456.000	100.00
RUNOFF	0.072	36374.152	0.53
EVAPOTRANSPIRATION	12.646	6426811.500	93.88
PERC./LEAKAGE THROUGH LAYER 1	0.233724	118778.492	1.74
CHANGE IN WATER STORAGE	0.518	263490.344	3.85
SOIL WATER AT START OF YEAR	1.484	754053.375	
SOIL WATER AT END OF YEAR	2.134	1084509.750	
SNOW WATER AT START OF YEAR	0.176	89516.305	1.31
SNOW WATER AT END OF YEAR	0.044	22550.312	0.33
ANNUAL WATER BUDGET BALANCE	0.0000	1.530	0.00

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ANNUAL TOTALS FOR YEAR 14

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.01	7119883.000	100.00
RUNOFF	0.155	78928.586	1.11
EVAPOTRANSPIRATION	13.587	6905072.000	96.98
PERC./LEAKAGE THROUGH LAYER 1	0.153963	78244.031	1.10
CHANGE IN WATER STORAGE	0.113	57636.328	0.81
SOIL WATER AT START OF YEAR	2.134	1084509.750	
SOIL WATER AT END OF YEAR	1.700	864039.562	
SNOW WATER AT START OF YEAR	0.044	22550.312	0.32
SNOW WATER AT END OF YEAR	0.592	300656.812	4.22
ANNUAL WATER BUDGET BALANCE	0.0000	2.310	0.00

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ANNUAL TOTALS FOR YEAR 15

	INCHES	CU. FEET	PERCENT
PRECIPITATION	13.68	6952177.500	100.00
RUNOFF	0.140	70955.016	1.02
EVAPOTRANSPIRATION	13.331	6774727.000	97.45
PERC./LEAKAGE THROUGH LAYER 1	0.237471	120682.727	1.74
CHANGE IN WATER STORAGE	-0.028	-14190.250	-0.20
SOIL WATER AT START OF YEAR	1.700	864039.562	
SOIL WATER AT END OF YEAR	2.264	1150506.120	
SNOW WATER AT START OF YEAR	0.592	300656.812	4.32
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	2.991	0.00

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ANNUAL TOTALS FOR YEAR 16

INCHES CU. FEET PERCENT

PRECIPITATION	14.35	7292669.500	100.00
RUNOFF	0.188	95548.914	1.31
EVAPOTRANSPIRATION	13.765	6995318.500	95.92
PERC./LEAKAGE THROUGH LAYER 1	0.271522	137987.703	1.89
CHANGE IN WATER STORAGE	0.126	63814.461	0.88
SOIL WATER AT START OF YEAR	2.264	1150506.120	
SOIL WATER AT END OF YEAR	2.389	1214320.620	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.227	0.00

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ANNUAL TOTALS FOR YEAR 17

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.02	7124966.500	100.00
RUNOFF	0.160	81472.211	1.14
EVAPOTRANSPIRATION	12.208	6204010.500	87.07
PERC./LEAKAGE THROUGH LAYER 1	0.492928	250506.203	3.52
CHANGE IN WATER STORAGE	1.159	588976.500	8.27
SOIL WATER AT START OF YEAR	2.389	1214320.620	
SOIL WATER AT END OF YEAR	3.087	1568689.120	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.462	234607.906	3.29
ANNUAL WATER BUDGET BALANCE	0.0000	1.060	0.00

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ANNUAL TOTALS FOR YEAR 18

	INCHES	CU. FEET	PERCENT
PRECIPITATION	15.81	8034642.500	100.00
RUNOFF	1.273	646758.875	8.05
EVAPOTRANSPIRATION	14.271	7252592.000	90.27
PERC./LEAKAGE THROUGH LAYER 1	1.395483	709184.500	8.83
CHANGE IN WATER STORAGE	-1.129	-573895.437	-7.14
SOIL WATER AT START OF YEAR	3.087	1568689.120	
SOIL WATER AT END OF YEAR	2.419	1229401.620	
SNOW WATER AT START OF YEAR	0.462	234607.906	2.92
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	2.726	0.00

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ANNUAL TOTALS FOR YEAR 19

	INCHES	CU. FEET	PERCENT
PRECIPITATION	9.07	4609374.500	100.00
RUNOFF	0.249	126303.711	2.74
EVAPOTRANSPIRATION	9.161	4655563.500	101.00
PERC./LEAKAGE THROUGH LAYER 1	0.107960	54865.258	1.19
CHANGE IN WATER STORAGE	-0.447	-227359.375	-4.93
SOIL WATER AT START OF YEAR	2.419	1229401.620	
SOIL WATER AT END OF YEAR	1.692	860060.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.279	141981.781	3.08
ANNUAL WATER BUDGET BALANCE	0.0000	1.106	0.00

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ANNUAL TOTALS FOR YEAR 20

	INCHES	CU. FEET	PERCENT
PRECIPITATION	18.14	9218749.000	100.00
RUNOFF	0.352	178838.031	1.94
EVAPOTRANSPIRATION	15.064	7655515.000	83.04
PERC./LEAKAGE THROUGH LAYER 1	0.329757	167582.297	1.82
CHANGE IN WATER STORAGE	2.394	1216813.000	13.20
SOIL WATER AT START OF YEAR	1.692	860060.500	
SOIL WATER AT END OF YEAR	4.366	2218855.250	
SNOW WATER AT START OF YEAR	0.279	141981.781	1.54
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.136	0.00

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ANNUAL TOTALS FOR YEAR 21

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.37	7302835.500	100.00
RUNOFF	0.225	114359.758	1.57
EVAPOTRANSPIRATION	14.765	7503790.500	102.75
PERC./LEAKAGE THROUGH LAYER 1	1.844062	937152.312	12.83
CHANGE IN WATER STORAGE	-2.465	-1252468.370	-17.15
SOIL WATER AT START OF YEAR	4.366	2218855.250	
SOIL WATER AT END OF YEAR	1.748	888322.937	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.154	78064.109	1.07
ANNUAL WATER BUDGET BALANCE	0.0000	1.333	0.00

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ANNUAL TOTALS FOR YEAR 22

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.01	8136283.000	100.00
RUNOFF	0.181	91762.969	1.13
EVAPOTRANSPIRATION	13.724	6974283.000	85.72
PERC./LEAKAGE THROUGH LAYER 1	0.302973	153970.656	1.89
CHANGE IN WATER STORAGE	1.803	916263.437	11.26
SOIL WATER AT START OF YEAR	1.748	888322.937	
SOIL WATER AT END OF YEAR	2.933	1490626.750	
SNOW WATER AT START OF YEAR	0.154	78064.102	0.96
SNOW WATER AT END OF YEAR	0.771	392023.781	4.82
ANNUAL WATER BUDGET BALANCE	0.0000	3.181	0.00

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ANNUAL TOTALS FOR YEAR 23

	INCHES	CU. FEET	PERCENT
PRECIPITATION	20.48	10407935.000	100.00
RUNOFF	1.508	766497.562	7.36
EVAPOTRANSPIRATION	17.884	9088705.000	87.32
PERC./LEAKAGE THROUGH LAYER 1	1.975172	1003782.560	9.64
CHANGE IN WATER STORAGE	-0.888	-451052.625	-4.33
SOIL WATER AT START OF YEAR	2.933	1490626.750	
SOIL WATER AT END OF YEAR	2.817	1431597.870	
SNOW WATER AT START OF YEAR	0.771	392023.812	3.77
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.939	0.00

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ANNUAL TOTALS FOR YEAR 24

	INCHES	CU. FEET	PERCENT
PRECIPITATION	15.44	7846608.500	100.00
RUNOFF	0.073	37299.199	0.48
EVAPOTRANSPIRATION	14.348	7291574.500	92.93
PERC./LEAKAGE THROUGH LAYER 1	0.446554	226938.500	2.89
CHANGE IN WATER STORAGE	0.572	290794.250	3.71
SOIL WATER AT START OF YEAR	2.817	1431597.870	
SOIL WATER AT END OF YEAR	3.133	1591943.120	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.257	130449.023	1.66
ANNUAL WATER BUDGET BALANCE	0.0000	1.939	0.00

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ANNUAL TOTALS FOR YEAR 25

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.57	7404475.500	100.00
RUNOFF	0.207	105440.320	1.42
EVAPOTRANSPIRATION	14.574	7406355.500	100.03
PERC./LEAKAGE THROUGH LAYER 1	0.994424	505366.344	6.83
CHANGE IN WATER STORAGE	-1.206	-612687.875	-8.27
SOIL WATER AT START OF YEAR	3.133	1591943.120	
SOIL WATER AT END OF YEAR	2.005	1018972.810	
SNOW WATER AT START OF YEAR	0.257	130449.023	1.76
SNOW WATER AT END OF YEAR	0.179	90731.453	1.23
ANNUAL WATER BUDGET BALANCE	0.0000	1.272	0.00

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ANNUAL TOTALS FOR YEAR 26

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.10	8182020.000	100.00
RUNOFF	0.203	103214.180	1.26
EVAPOTRANSPIRATION	13.918	7072889.500	86.44
PERC./LEAKAGE THROUGH LAYER 1	1.031630	524274.156	6.41
CHANGE IN WATER STORAGE	0.948	481643.219	5.89
SOIL WATER AT START OF YEAR	2.005	1018972.810	
SOIL WATER AT END OF YEAR	3.131	1591347.500	
SNOW WATER AT START OF YEAR	0.179	90731.445	1.11
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.606	0.00

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ANNUAL TOTALS FOR YEAR 27

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.00	8131201.000	100.00
RUNOFF	0.056	28310.523	0.35
EVAPOTRANSPIRATION	14.750	7495875.000	92.19
PERC./LEAKAGE THROUGH LAYER 1	1.208146	613980.000	7.55
CHANGE IN WATER STORAGE	-0.014	-6966.252	-0.09
SOIL WATER AT START OF YEAR	3.131	1591347.500	
SOIL WATER AT END OF YEAR	2.630	1336367.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.488	248014.250	3.05
ANNUAL WATER BUDGET BALANCE	0.0000	1.817	0.00

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ANNUAL TOTALS FOR YEAR 28

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.69	8481860.000	100.00
RUNOFF	0.046	23365.229	0.28
EVAPOTRANSPIRATION	13.900	7064219.500	83.29
PERC./LEAKAGE THROUGH LAYER 1	1.700339	864112.375	10.19
CHANGE IN WATER STORAGE	1.043	530162.062	6.25
SOIL WATER AT START OF YEAR	2.630	1336367.000	
SOIL WATER AT END OF YEAR	3.824	1943275.370	
SNOW WATER AT START OF YEAR	0.488	248014.250	2.92
SNOW WATER AT END OF YEAR	0.337	171267.969	2.02
ANNUAL WATER BUDGET BALANCE	0.0000	0.848	0.00

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ANNUAL TOTALS FOR YEAR 29

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.66	8466614.000	100.00
RUNOFF	0.120	61008.266	0.72
EVAPOTRANSPIRATION	17.229	8755915.000	103.42
PERC./LEAKAGE THROUGH LAYER 1	1.488057	756230.375	8.93
CHANGE IN WATER STORAGE	-2.177	-1106538.250	-13.07
SOIL WATER AT START OF YEAR	3.824	1943275.370	
SOIL WATER AT END OF YEAR	1.983	1008005.000	
SNOW WATER AT START OF YEAR	0.337	171267.969	2.02
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-1.999	0.00

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ANNUAL TOTALS FOR YEAR 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	12.38	6291517.000	100.00
RUNOFF	0.067	33920.316	0.54
EVAPOTRANSPIRATION	11.822	6008072.500	95.49
PERC./LEAKAGE THROUGH LAYER 1	0.366342	186175.000	2.96
CHANGE IN WATER STORAGE	0.125	63349.918	1.01
SOIL WATER AT START OF YEAR	1.983	1008005.000	
SOIL WATER AT END OF YEAR	2.108	1071354.870	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.004	2190.594	0.03
ANNUAL WATER BUDGET BALANCE	0.0000	-0.682	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.16	1.20	1.95	2.04	1.30	1.03
	0.69	0.85	0.84	1.05	1.31	1.46
STD. DEVIATIONS	0.60	0.54	0.77	0.87	0.68	0.74
	0.48	0.80	0.61	0.82	0.73	0.59
RUNOFF						
TOTALS	0.128	0.068	0.032	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.020
STD. DEVIATIONS	0.315	0.118	0.062	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.072
EVAPOTRANSPIRATION						
TOTALS	0.834	1.099	1.816	1.888	1.507	1.978
	0.746	0.750	0.878	0.818	0.790	0.795
STD. DEVIATIONS	0.128	0.260	0.478	0.651	0.688	0.743
	0.473	0.728	0.555	0.639	0.315	0.208
PERCOLATION/LEAKAGE THROUGH LAYER 1						
TOTALS	0.0111	0.0013	0.0704	0.1416	0.1757	0.2553
	0.0058	0.0074	0.0063	0.0131	0.0087	0.0349
STD. DEVIATIONS	0.0606	0.0067	0.1799	0.1967	0.1795	0.1692
	0.0161	0.0150	0.0092	0.0336	0.0134	0.1741

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.88 (2.435)	7561340.5	100.00
RUNOFF	0.248 (0.3500)	125972.27	1.666
EVAPOTRANSPIRATION	13.900 (1.9390)	7063881.50	93.421
PERCOLATION/LEAKAGE THROUGH LAYER 1	0.73160 (0.61313)	371798.250	4.91709
CHANGE IN WATER STORAGE	-0.002 (1.0447)	-1075.37	-0.014

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	1.66	843612.000
RUNOFF	1.336	678866.1870
PERCOLATION/LEAKAGE THROUGH LAYER 1	0.168075	85415.67970
SNOW WATER	2.13	1082936.7500
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.2107
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0387

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	???????????	?????????

SNOW WATER 0.000

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.03  (31 DECEMBER 1994)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\HELP3\data4.D4
TEMPERATURE DATA FILE:      C:\HELP3\data7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\data13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\data11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\scs12.D10
OUTPUT DATA FILE:           C:\HELP3\scs12.OUT

TIME:  15:11     DATE:  12/ 9/1998

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     TITLE:  ET Landfill Cover (4-layers, 140 ac, 4%, 350 ft) SCS12

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
               COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   8
           THICKNESS                 =      6.00   INCHES
           POROSITY                  =      0.4630 VOL/VOL
           FIELD CAPACITY            =      0.2320 VOL/VOL
           WILTING POINT             =      0.1160 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.1928 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.369999994000E-03 CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  2.49
                   FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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                         LAYER  2
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             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =    24.00   INCHES
   POROSITY                     =     0.4530 VOL/VOL
   FIELD CAPACITY               =     0.1900 VOL/VOL
   WILTING POINT                =     0.0850 VOL/VOL
   INITIAL SOIL WATER CONTENT   =     0.1001 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.200000009000E-02 CM/SEC
   SLOPE                        =     4.00   PERCENT
   DRAINAGE LENGTH              =   350.0    FEET

                         LAYER  3
                         --------

               TYPE 3 - BARRIER SOIL LINER
               MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =    18.00   INCHES
   POROSITY                     =     0.4610 VOL/VOL
   FIELD CAPACITY               =     0.3600 VOL/VOL
   WILTING POINT                =     0.2030 VOL/VOL
   INITIAL SOIL WATER CONTENT   =     0.4610 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-05 CM/SEC

                         LAYER  4
                         --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =    30.00   INCHES
   POROSITY                     =     0.4530 VOL/VOL
   FIELD CAPACITY               =     0.1900 VOL/VOL
   WILTING POINT                =     0.0850 VOL/VOL
   INITIAL SOIL WATER CONTENT   =     0.1681 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.200000009000E-02 CM/SEC


           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

  NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
         SOIL DATA BASE USING SOIL TEXTURE # 8 WITH A
         FAIR STAND OF GRASS, A SURFACE SLOPE OF  4.%
         AND A SLOPE LENGTH OF  350. FEET.

SCS RUNOFF CURVE NUMBER             =     79.40
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =    140.000  ACRES
EVAPORATIVE ZONE DEPTH              =     30.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      3.558  INCHES
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UPPER LIMIT OF EVAPORATIVE STORAGE  =     13.650  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      2.736  INCHES
INITIAL SNOW WATER                  =      0.175  INCHES
INITIAL WATER IN LAYER MATERIALS    =     15.891  INCHES
TOTAL INITIAL WATER                 =     16.065  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
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EVAPOTRANSPIRATION AND WEATHER DATA

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NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         Salt Lake City        Utah

     MAXIMUM LEAF AREA INDEX                    =  1.60
     START OF GROWING SEASON (JULIAN DATE)  =   117
     END OF GROWING SEASON (JULIAN DATE)    =   289
     AVERAGE ANNUAL WIND SPEED              =  8.80 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY  = 67.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY  = 48.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY  = 39.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY  = 65.00 %

NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR     SALT LAKE CITY      UTAH
```

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.35	1.33	1.72	2.21	1.47	0.97
0.72	0.92	0.89	1.14	1.22	1.37

```
NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR     SALT LAKE CITY      UTAH
```

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.60	34.10	40.70	49.20	58.80	68.30
77.50	74.90	65.00	53.00	39.70	30.30

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NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR     SALT LAKE CITY      UTAH

              STATION LATITUDE  = 40.76 DEGREES
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ANNUAL TOTALS FOR YEAR   1

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                                          INCHES          CU. FEET     PERCENT
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PRECIPITATION	12.09	6144138.500	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	12.106	6152392.000	100.13
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
PERC./LEAKAGE THROUGH LAYER 4	0.298206	151548.078	2.47
CHANGE IN WATER STORAGE	-0.314	-159802.656	-2.60
SOIL WATER AT START OF YEAR	15.890	8075511.500	
SOIL WATER AT END OF YEAR	15.576	7915709.000	
SNOW WATER AT START OF YEAR	0.175	88898.516	1.45
SNOW WATER AT END OF YEAR	0.175	88898.516	1.45
ANNUAL WATER BUDGET BALANCE	0.0000	1.348	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
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PRECIPITATION	15.65	7953330.500	100.00
RUNOFF	0.131	66411.250	0.84
EVAPOTRANSPIRATION	15.908	8084394.500	101.65
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
PERC./LEAKAGE THROUGH LAYER 4	0.146849	74628.625	0.94
CHANGE IN WATER STORAGE	-0.535	-272104.281	-3.42
SOIL WATER AT START OF YEAR	15.576	7915709.000	
SOIL WATER AT END OF YEAR	15.215	7732503.000	
SNOW WATER AT START OF YEAR	0.175	88898.516	1.12

SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.008	0.00

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	10.33	5249706.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	9.904	5033209.500	95.88
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
PERC./LEAKAGE THROUGH LAYER 4	0.096274	48926.676	0.93
CHANGE IN WATER STORAGE	0.330	167568.828	3.19
SOIL WATER AT START OF YEAR	15.215	7732503.000	
SOIL WATER AT END OF YEAR	14.600	7419542.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.946	480529.500	9.15
ANNUAL WATER BUDGET BALANCE	0.0000	0.901	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	18.28	9289896.000	100.00
RUNOFF	0.587	298514.656	3.21
EVAPOTRANSPIRATION	16.881	8578692.000	92.34
DRAINAGE COLLECTED FROM LAYER 2	0.0000	14.566	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.755545	383967.812	4.13
AVG. HEAD ON TOP OF LAYER 3	0.0005		

PERC./LEAKAGE THROUGH LAYER 4	0.285170	144923.391	1.56
CHANGE IN WATER STORAGE	0.527	267749.781	2.88
SOIL WATER AT START OF YEAR	14.600	7419542.500	
SOIL WATER AT END OF YEAR	16.026	8144649.000	
SNOW WATER AT START OF YEAR	0.946	480529.500	5.17
SNOW WATER AT END OF YEAR	0.046	23172.334	0.25
ANNUAL WATER BUDGET BALANCE	0.0000	2.151	0.00

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ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	12.76	6484631.500	100.00
RUNOFF	0.061	30759.926	0.47
EVAPOTRANSPIRATION	13.403	6811378.000	105.04
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.847	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.050429	25628.133	0.40
AVG. HEAD ON TOP OF LAYER 3	0.0000		
PERC./LEAKAGE THROUGH LAYER 4	0.262719	133513.812	2.06
CHANGE IN WATER STORAGE	-0.966	-491021.719	-7.57
SOIL WATER AT START OF YEAR	16.026	8144649.000	
SOIL WATER AT END OF YEAR	15.106	7676800.000	
SNOW WATER AT START OF YEAR	0.046	23172.334	0.36
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.863	0.00

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ANNUAL TOTALS FOR YEAR 6

	INCHES	CU. FEET	PERCENT
PRECIPITATION	17.91	9101860.000	100.00

RUNOFF	0.103	52336.535	0.58
EVAPOTRANSPIRATION	16.479	8374397.000	92.01
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
PERC./LEAKAGE THROUGH LAYER 4	0.152916	77711.852	0.85
CHANGE IN WATER STORAGE	1.176	597414.750	6.56
SOIL WATER AT START OF YEAR	15.106	7676800.000	
SOIL WATER AT END OF YEAR	16.281	8274214.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.027	13673.017	0.15
ANNUAL WATER BUDGET BALANCE	0.0000	-0.295	0.00

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ANNUAL TOTALS FOR YEAR 7

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.95	7597591.000	100.00
RUNOFF	0.019	9476.142	0.12
EVAPOTRANSPIRATION	15.851	8055666.500	106.03
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
PERC./LEAKAGE THROUGH LAYER 4	0.098920	50271.281	0.66
CHANGE IN WATER STORAGE	-1.046	-531496.250	-7.00
SOIL WATER AT START OF YEAR	16.281	8274214.500	
SOIL WATER AT END OF YEAR	14.715	7478238.500	
SNOW WATER AT START OF YEAR	0.027	13673.017	0.18
SNOW WATER AT END OF YEAR	0.547	278152.656	3.66
ANNUAL WATER BUDGET BALANCE	0.0269	13673.083	0.18

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ANNUAL TOTALS FOR YEAR 8

	INCHES	CU. FEET	PERCENT
PRECIPITATION	12.22	6210204.000	100.00
RUNOFF	0.056	28460.908	0.46
EVAPOTRANSPIRATION	11.626	5908407.000	95.14
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
PERC./LEAKAGE THROUGH LAYER 4	0.072681	36936.684	0.59
CHANGE IN WATER STORAGE	0.465	236399.250	3.81
SOIL WATER AT START OF YEAR	14.715	7478238.500	
SOIL WATER AT END OF YEAR	15.605	7930420.500	
SNOW WATER AT START OF YEAR	0.547	278152.656	4.48
SNOW WATER AT END OF YEAR	0.123	62370.070	1.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.208	0.00

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ANNUAL TOTALS FOR YEAR 9

	INCHES	CU. FEET	PERCENT
PRECIPITATION	17.05	8664811.000	100.00
RUNOFF	0.725	368627.625	4.25
EVAPOTRANSPIRATION	16.207	8236572.000	95.06
DRAINAGE COLLECTED FROM LAYER 2	0.0001	36.140	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.901055	457916.156	5.28

AVG. HEAD ON TOP OF LAYER 3	0.0007		
PERC./LEAKAGE THROUGH LAYER 4	0.326123	165735.469	1.91
CHANGE IN WATER STORAGE	-0.209	-106160.797	-1.23
SOIL WATER AT START OF YEAR	15.605	7930420.500	
SOIL WATER AT END OF YEAR	15.519	7886630.000	
SNOW WATER AT START OF YEAR	0.123	62370.070	0.72
SNOW WATER AT END OF YEAR	0.018	9212.187	0.11
ANNUAL WATER BUDGET BALANCE	0.0000	-0.121	0.00

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ANNUAL TOTALS FOR YEAR 10

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.16	7196113.000	100.00
RUNOFF	0.249	126465.477	1.76
EVAPOTRANSPIRATION	13.395	6807312.500	94.60
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
PERC./LEAKAGE THROUGH LAYER 4	0.278411	141488.594	1.97
CHANGE IN WATER STORAGE	0.220	111632.266	1.55
SOIL WATER AT START OF YEAR	15.519	7886630.000	
SOIL WATER AT END OF YEAR	15.757	8007474.500	
SNOW WATER AT START OF YEAR	0.018	9212.187	0.13
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0181	9213.986	0.13

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ANNUAL TOTALS FOR YEAR 11

	INCHES	CU. FEET	PERCENT

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.61	8441203.000	100.00
RUNOFF	0.028	14397.146	0.17
EVAPOTRANSPIRATION	15.901	8080822.500	95.73
DRAINAGE COLLECTED FROM LAYER 2	0.0000	2.344	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.194084	98633.695	1.17
AVG. HEAD ON TOP OF LAYER 3	0.0001		
PERC./LEAKAGE THROUGH LAYER 4	0.159900	81261.117	0.96
CHANGE IN WATER STORAGE	0.521	264716.406	3.14
SOIL WATER AT START OF YEAR	15.757	8007474.500	
SOIL WATER AT END OF YEAR	16.225	8245398.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.053	26792.830	0.32
ANNUAL WATER BUDGET BALANCE	0.0000	3.953	0.00

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ANNUAL TOTALS FOR YEAR 12

	INCHES	CU. FEET	PERCENT
PRECIPITATION	13.10	6657419.500	100.00
RUNOFF	0.145	73684.383	1.11
EVAPOTRANSPIRATION	13.984	7106456.000	106.74
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
PERC./LEAKAGE THROUGH LAYER 4	0.155753	79153.922	1.19
CHANGE IN WATER STORAGE	-1.184	-601874.937	-9.04
SOIL WATER AT START OF YEAR	16.225	8245398.000	
SOIL WATER AT END OF YEAR	14.917	7580799.500	
SNOW WATER AT START OF YEAR	0.053	26792.830	0.40

SNOW WATER AT END OF YEAR	0.176	89516.305	1.34
ANNUAL WATER BUDGET BALANCE	0.0000	0.204	0.00

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ANNUAL TOTALS FOR YEAR 13

	INCHES	CU. FEET	PERCENT
PRECIPITATION	13.47	6845456.000	100.00
RUNOFF	0.066	33603.836	0.49
EVAPOTRANSPIRATION	12.432	6318182.000	92.30
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
PERC./LEAKAGE THROUGH LAYER 4	0.099912	50775.469	0.74
CHANGE IN WATER STORAGE	0.871	442892.969	6.47
SOIL WATER AT START OF YEAR	14.917	7580799.500	
SOIL WATER AT END OF YEAR	15.920	8090658.500	
SNOW WATER AT START OF YEAR	0.176	89516.305	1.31
SNOW WATER AT END OF YEAR	0.044	22550.312	0.33
ANNUAL WATER BUDGET BALANCE	0.0000	1.886	0.00

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ANNUAL TOTALS FOR YEAR 14

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.01	7119883.000	100.00
RUNOFF	0.158	80310.297	1.13
EVAPOTRANSPIRATION	14.147	7189749.500	100.98
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		

PERC./LEAKAGE THROUGH LAYER 4	0.073068	37133.297	0.52
CHANGE IN WATER STORAGE	-0.369	-187312.312	-2.63
SOIL WATER AT START OF YEAR	15.920	8090658.500	
SOIL WATER AT END OF YEAR	15.004	7625239.500	
SNOW WATER AT START OF YEAR	0.044	22550.312	0.32
SNOW WATER AT END OF YEAR	0.592	300656.812	4.22
ANNUAL WATER BUDGET BALANCE	0.0000	2.465	0.00

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ANNUAL TOTALS FOR YEAR 15

	INCHES	CU. FEET	PERCENT
PRECIPITATION	13.68	6952177.500	100.00
RUNOFF	0.129	65554.734	0.94
EVAPOTRANSPIRATION	13.486	6853683.000	98.58
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
PERC./LEAKAGE THROUGH LAYER 4	0.057268	29103.666	0.42
CHANGE IN WATER STORAGE	0.008	3834.942	0.06
SOIL WATER AT START OF YEAR	15.004	7625239.500	
SOIL WATER AT END OF YEAR	15.604	7929731.500	
SNOW WATER AT START OF YEAR	0.592	300656.812	4.32
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.132	0.00

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ANNUAL TOTALS FOR YEAR 16

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.35	7292669.500	100.00

RUNOFF	0.200	101797.172	1.40
EVAPOTRANSPIRATION	13.811	7018682.500	96.24
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
PERC./LEAKAGE THROUGH LAYER 4	0.047046	23908.619	0.33
CHANGE IN WATER STORAGE	0.292	148278.469	2.03
SOIL WATER AT START OF YEAR	15.604	7929731.500	
SOIL WATER AT END OF YEAR	15.895	8078010.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	3.160	0.00

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ANNUAL TOTALS FOR YEAR 17

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.02	7124966.500	100.00
RUNOFF	0.200	101753.531	1.43
EVAPOTRANSPIRATION	12.587	6396528.000	89.78
DRAINAGE COLLECTED FROM LAYER 2	0.0000	2.845	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.180349	91653.312	1.29
AVG. HEAD ON TOP OF LAYER 3	0.0001		
PERC./LEAKAGE THROUGH LAYER 4	0.019484	9901.786	0.14
CHANGE IN WATER STORAGE	1.214	616775.687	8.66
SOIL WATER AT START OF YEAR	15.895	8078010.000	
SOIL WATER AT END OF YEAR	16.647	8460178.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.462	234607.906	3.29
ANNUAL WATER BUDGET BALANCE	0.0000	4.589	0.00

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ANNUAL TOTALS FOR YEAR 18

	INCHES	CU. FEET	PERCENT
PRECIPITATION	15.81	8034642.500	100.00
RUNOFF	1.280	650447.500	8.10
EVAPOTRANSPIRATION	15.255	7752777.000	96.49
DRAINAGE COLLECTED FROM LAYER 2	0.0000	11.695	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.374901	190524.719	2.37
AVG. HEAD ON TOP OF LAYER 3	0.0003		
PERC./LEAKAGE THROUGH LAYER 4	0.089762	45616.867	0.57
CHANGE IN WATER STORAGE	-0.815	-414209.281	-5.16
SOIL WATER AT START OF YEAR	16.647	8460178.000	
SOIL WATER AT END OF YEAR	16.294	8280576.000	
SNOW WATER AT START OF YEAR	0.462	234607.906	2.92
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-1.261	0.00

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ANNUAL TOTALS FOR YEAR 19

	INCHES	CU. FEET	PERCENT
PRECIPITATION	9.07	4609374.500	100.00
RUNOFF	0.249	126481.648	2.74
EVAPOTRANSPIRATION	9.479	4817073.000	104.51
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
PERC./LEAKAGE THROUGH LAYER 4	0.160803	81720.336	1.77
CHANGE IN WATER STORAGE	-0.818	-415900.937	-9.02

SOIL WATER AT START OF YEAR	16.294	8280576.000	
SOIL WATER AT END OF YEAR	15.196	7722693.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.279	141981.781	3.08
ANNUAL WATER BUDGET BALANCE	0.0000	0.515	0.00

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ANNUAL TOTALS FOR YEAR 20

	INCHES	CU. FEET	PERCENT
PRECIPITATION	18.14	9218749.000	100.00
RUNOFF	0.342	173677.359	1.88
EVAPOTRANSPIRATION	15.054	7650304.500	82.99
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
PERC./LEAKAGE THROUGH LAYER 4	0.102580	52131.379	0.57
CHANGE IN WATER STORAGE	2.642	1342633.500	14.56
SOIL WATER AT START OF YEAR	15.196	7722693.500	
SOIL WATER AT END OF YEAR	18.117	9207309.000	
SNOW WATER AT START OF YEAR	0.279	141981.781	1.54
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.783	0.00

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ANNUAL TOTALS FOR YEAR 21

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.37	7302835.500	100.00

RUNOFF	0.243	123636.305	1.69
EVAPOTRANSPIRATION	15.070	7658362.000	104.87
DRAINAGE COLLECTED FROM LAYER 2	0.0002	95.469	0.00
PERC./LEAKAGE THROUGH LAYER 3	2.036788	1035095.620	14.17
AVG. HEAD ON TOP OF LAYER 3	0.0016		
PERC./LEAKAGE THROUGH LAYER 4	1.482908	753613.625	10.32
CHANGE IN WATER STORAGE	-2.426	-1232874.250	-16.88
SOIL WATER AT START OF YEAR	18.117	9207309.000	
SOIL WATER AT END OF YEAR	15.538	7896370.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.154	78064.109	1.07
ANNUAL WATER BUDGET BALANCE	0.0000	2.181	0.00

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ANNUAL TOTALS FOR YEAR 22

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.01	8136283.000	100.00
RUNOFF	0.167	84749.273	1.04
EVAPOTRANSPIRATION	13.717	6970990.000	85.68
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
PERC./LEAKAGE THROUGH LAYER 4	0.314654	159906.969	1.97
CHANGE IN WATER STORAGE	1.812	920638.625	11.32
SOIL WATER AT START OF YEAR	15.538	7896370.500	
SOIL WATER AT END OF YEAR	16.732	8503049.000	
SNOW WATER AT START OF YEAR	0.154	78064.102	0.96
SNOW WATER AT END OF YEAR	0.771	392023.781	4.82
ANNUAL WATER BUDGET BALANCE	0.0000	-1.848	0.00

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ANNUAL TOTALS FOR YEAR 23

	INCHES	CU. FEET	PERCENT
PRECIPITATION	20.48	10407935.000	100.00
RUNOFF	1.496	760054.437	7.30
EVAPOTRANSPIRATION	18.277	9288192.000	89.24
DRAINAGE COLLECTED FROM LAYER 2	0.0001	64.094	0.00
PERC./LEAKAGE THROUGH LAYER 3	1.476547	750381.125	7.21
AVG. HEAD ON TOP OF LAYER 3	0.0012		
PERC./LEAKAGE THROUGH LAYER 4	1.151645	585266.125	5.62
CHANGE IN WATER STORAGE	-0.444	-225640.953	-2.17
SOIL WATER AT START OF YEAR	16.732	8503049.000	
SOIL WATER AT END OF YEAR	17.059	8669432.000	
SNOW WATER AT START OF YEAR	0.771	392023.812	3.77
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-1.212	0.00

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ANNUAL TOTALS FOR YEAR 24

	INCHES	CU. FEET	PERCENT
PRECIPITATION	15.44	7846608.500	100.00
RUNOFF	0.071	36271.875	0.46
EVAPOTRANSPIRATION	14.911	7577540.000	96.57
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.090	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.003413	1734.533	0.02
AVG. HEAD ON TOP OF LAYER 3	0.0000		
PERC./LEAKAGE THROUGH LAYER 4	0.322099	163690.516	2.09
CHANGE IN WATER STORAGE	0.136	69104.008	0.88

SOIL WATER AT START OF YEAR	17.059	8669432.000	
SOIL WATER AT END OF YEAR	16.938	8608087.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.257	130449.023	1.66
ANNUAL WATER BUDGET BALANCE	0.0000	1.666	0.00

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ANNUAL TOTALS FOR YEAR 25

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.57	7404475.500	100.00
RUNOFF	0.217	110057.250	1.49
EVAPOTRANSPIRATION	14.862	7552848.000	102.00
DRAINAGE COLLECTED FROM LAYER 2	0.0000	21.235	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.836548	425133.594	5.74
AVG. HEAD ON TOP OF LAYER 3	0.0006		
PERC./LEAKAGE THROUGH LAYER 4	0.547575	278277.406	3.76
CHANGE IN WATER STORAGE	-1.056	-536729.687	-7.25
SOIL WATER AT START OF YEAR	16.938	8608087.000	
SOIL WATER AT END OF YEAR	15.960	8111075.000	
SNOW WATER AT START OF YEAR	0.257	130449.023	1.76
SNOW WATER AT END OF YEAR	0.179	90731.453	1.23
ANNUAL WATER BUDGET BALANCE	0.0000	1.363	0.00

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ANNUAL TOTALS FOR YEAR 26

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.10	8182020.000	100.00
RUNOFF	0.194	98540.508	1.20
EVAPOTRANSPIRATION	14.116	7173672.000	87.68
DRAINAGE COLLECTED FROM LAYER 2	0.0000	16.462	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.760859	386668.562	4.73
AVG. HEAD ON TOP OF LAYER 3	0.0006		
PERC./LEAKAGE THROUGH LAYER 4	0.746589	379416.625	4.64
CHANGE IN WATER STORAGE	1.044	530375.250	6.48

SOIL WATER AT START OF YEAR	15.960	8111075.000	
SOIL WATER AT END OF YEAR	17.183	8732182.000	
SNOW WATER AT START OF YEAR	0.179	90731.445	1.11
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.485	0.00

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ANNUAL TOTALS FOR YEAR 27

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.00	8131201.000	100.00
RUNOFF	0.050	25196.076	0.31
EVAPOTRANSPIRATION	16.069	8166269.000	100.43
DRAINAGE COLLECTED FROM LAYER 2	0.0000	2.491	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.070444	35799.625	0.44
AVG. HEAD ON TOP OF LAYER 3	0.0001		
PERC./LEAKAGE THROUGH LAYER 4	0.324230	164773.531	2.03
CHANGE IN WATER STORAGE	-0.443	-225042.281	-2.77
SOIL WATER AT START OF YEAR	17.183	8732182.000	
SOIL WATER AT END OF YEAR	16.252	8259125.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.488	248014.250	3.05
ANNUAL WATER BUDGET BALANCE	0.0000	2.332	0.00

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ANNUAL TOTALS FOR YEAR 28

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.69	8481860.000	100.00
RUNOFF	0.051	25984.285	0.31
EVAPOTRANSPIRATION	13.998	7113683.500	83.87

DRAINAGE COLLECTED FROM LAYER 2	0.0001	48.199	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.802313	407735.250	4.81
AVG. HEAD ON TOP OF LAYER 3	0.0006		
PERC./LEAKAGE THROUGH LAYER 4	0.195346	99274.977	1.17
CHANGE IN WATER STORAGE	2.446	1242867.870	14.65
SOIL WATER AT START OF YEAR	16.252	8259125.500	
SOIL WATER AT END OF YEAR	18.848	9578739.000	
SNOW WATER AT START OF YEAR	0.488	248014.250	2.92
SNOW WATER AT END OF YEAR	0.337	171267.969	2.02
ANNUAL WATER BUDGET BALANCE	0.0000	1.477	0.00

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ANNUAL TOTALS FOR YEAR 29

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.66	8466614.000	100.00
RUNOFF	0.113	57518.301	0.68
EVAPOTRANSPIRATION	17.719	9004654.000	106.35
DRAINAGE COLLECTED FROM LAYER 2	0.0001	68.055	0.00
PERC./LEAKAGE THROUGH LAYER 3	1.826111	928029.812	10.96
AVG. HEAD ON TOP OF LAYER 3	0.0015		
PERC./LEAKAGE THROUGH LAYER 4	2.158705	1097054.120	12.96
CHANGE IN WATER STORAGE	-3.331	-1692677.000	-19.99
SOIL WATER AT START OF YEAR	18.848	9578739.000	
SOIL WATER AT END OF YEAR	15.855	8057330.500	
SNOW WATER AT START OF YEAR	0.337	171267.969	2.02
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-3.877	0.00

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ANNUAL TOTALS FOR YEAR 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	12.38	6291517.000	100.00
RUNOFF	0.067	33911.418	0.54
EVAPOTRANSPIRATION	12.322	6261831.000	99.53
DRAINAGE COLLECTED FROM LAYER 2	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 3	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
PERC./LEAKAGE THROUGH LAYER 4	0.324454	164887.297	2.62
CHANGE IN WATER STORAGE	-0.333	-169112.437	-2.69
SOIL WATER AT START OF YEAR	15.855	8057330.500	
SOIL WATER AT END OF YEAR	15.522	7888218.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.004	2190.594	0.03
ANNUAL WATER BUDGET BALANCE	0.0000	-0.045	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.16	1.20	1.95	2.04	1.30	1.03
	0.69	0.85	0.84	1.05	1.31	1.46
STD. DEVIATIONS	0.60	0.54	0.77	0.87	0.68	0.74
	0.48	0.80	0.61	0.82	0.73	0.59
RUNOFF						
TOTALS	0.126	0.068	0.032	0.001	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.020
STD. DEVIATIONS	0.312	0.119	0.060	0.003	0.000	0.000
	0.000	0.000	0.000	0.000	0.001	0.072

EVAPOTRANSPIRATION

TOTALS	0.775	1.043	2.158	2.326	1.546	1.642
	0.802	0.785	0.847	0.818	0.801	0.755
STD. DEVIATIONS	0.131	0.208	0.342	0.866	0.817	0.804
	0.532	0.795	0.559	0.631	0.278	0.163

LATERAL DRAINAGE COLLECTED FROM LAYER 2

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 3

TOTALS	0.0038	0.0000	0.0894	0.0938	0.0596	0.0755
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0201
STD. DEVIATIONS	0.0210	0.0000	0.2781	0.1971	0.1478	0.1001
	0.0000	0.0000	0.0000	0.0000	0.0000	0.1099

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0208	0.0177	0.0183	0.0437	0.0519	0.0347
	0.0399	0.0325	0.0269	0.0245	0.0212	0.0195
STD. DEVIATIONS	0.0173	0.0164	0.0157	0.1193	0.1259	0.0625
	0.0654	0.0397	0.0285	0.0230	0.0182	0.0160

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3

AVERAGES	0.0000	0.0000	0.0008	0.0009	0.0005	0.0007
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
STD. DEVIATIONS	0.0002	0.0000	0.0026	0.0019	0.0013	0.0009
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.88 (2.435)	7561340.5	100.00

RUNOFF	0.247	(0.3496)	125289.34	1.657
EVAPOTRANSPIRATION	14.298	(2.0676)	7266491.00	96.101
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0.00003	(0.00005)	12.818	0.00017
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.34231	(0.57749)	173963.422	2.30070
AVERAGE HEAD ACROSS TOP OF LAYER 3	0.000	(0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.35174	(0.46942)	178751.734	2.36402
CHANGE IN WATER STORAGE	-0.020	(1.2579)	-9969.23	-0.132

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            PEAK DAILY VALUES FOR YEARS    1 THROUGH   30
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                                            (INCHES)      (CU. FT.)
                                           ----------   -------------
      PRECIPITATION                           1.66       843612.000

      RUNOFF                                  1.329      675191.2500

      DRAINAGE COLLECTED FROM LAYER  2        0.00003        15.33921

      PERCOLATION/LEAKAGE THROUGH LAYER  3    0.116592    59251.87110

      AVERAGE HEAD ACROSS LAYER  3            0.036

      PERCOLATION/LEAKAGE THROUGH LAYER  4    0.046445    23603.36520

      SNOW WATER                              2.13      1082936.7500


      MAXIMUM VEG. SOIL WATER (VOL/VOL)               0.2389

      MINIMUM VEG. SOIL WATER (VOL/VOL)               0.0799
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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	1.3468	0.2245
2	2.1251	0.0885
3	8.2980	0.4610
4	3.7521	0.1563
SNOW WATER	0.000	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**             HELP MODEL VERSION 3.03  (31 DECEMBER 1994)                  **
**                DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
**                  USAE WATERWAYS EXPERIMENT STATION                       **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:    C:\MYDOCU~1\HELP3\data4.D4
TEMPERATURE DATA FILE:      C:\MYDOCU~1\HELP3\data7.D7
SOLAR RADIATION DATA FILE:  C:\MYDOCU~1\HELP3\data13.D13
EVAPOTRANSPIRATION DATA:    C:\MYDOCU~1\HELP3\data11.D11
SOIL AND DESIGN DATA FILE:  C:\MYDOCU~1\HELP3\Data99.D10
OUTPUT DATA FILE:           C:\MYDOCU~1\HELP3\Data99.OUT


TIME:   9:28     DATE:   2/16/2000

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     TITLE:  Multi-Layer Landfill Cap(7-layers, 140 ac, 4% 350 ft) SWMU 12/15

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   8
           THICKNESS                 =      6.00   INCHES
           POROSITY                  =      0.4630 VOL/VOL
           FIELD CAPACITY            =      0.2320 VOL/VOL
           WILTING POINT             =      0.1160 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.1687 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.369999994000E-03 CM/SEC
       NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  2.49
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 6

```
THICKNESS                  =     24.00   INCHES
POROSITY                   =      0.4530 VOL/VOL
FIELD CAPACITY             =      0.1900 VOL/VOL
WILTING POINT              =      0.0850 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.1518 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.720000011000E-03 CM/SEC
```

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 34

```
THICKNESS                  =      0.25   INCHES
POROSITY                   =      0.8500 VOL/VOL
FIELD CAPACITY             =      0.0100 VOL/VOL
WILTING POINT              =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =   33.0000000000     CM/SEC
SLOPE                      =      4.00   PERCENT
DRAINAGE LENGTH            =    350.0    FEET
```

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

```
THICKNESS                  =      0.04   INCHES
POROSITY                   =      0.0000 VOL/VOL
FIELD CAPACITY             =      0.0000 VOL/VOL
WILTING POINT              =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY        =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS   =      4.00   HOLES/ACRE
FML PLACEMENT QUALITY      =  3 - GOOD
```

LAYER 5

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

```
THICKNESS                  =      0.70   INCHES
POROSITY                   =      0.7500 VOL/VOL
FIELD CAPACITY             =      0.7470 VOL/VOL
WILTING POINT              =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.499999997000E-08 CM/SEC
```

LAYER 6

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 34

```
THICKNESS                    =      0.25   INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0091 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =   33.0000000000     CM/SEC
```

LAYER 7

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 6

```
THICKNESS                    =     30.00   INCHES
POROSITY                     =      0.4530 VOL/VOL
FIELD CAPACITY               =      0.1900 VOL/VOL
WILTING POINT                =      0.0850 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1741 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.720000011000E-03 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 8 WITH A
FAIR STAND OF GRASS, A SURFACE SLOPE OF 4.%
AND A SLOPE LENGTH OF 350. FEET.

```
SCS RUNOFF CURVE NUMBER              =     79.40
FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =    140.000  ACRES
EVAPORATIVE ZONE DEPTH               =     30.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =      4.655  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =     13.650  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =      2.736  INCHES
INITIAL SNOW WATER                   =      0.175  INCHES
INITIAL WATER IN LAYER MATERIALS     =     10.408  INCHES
TOTAL INITIAL WATER                  =     10.583  INCHES
TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Salt Lake City   Utah

```
MAXIMUM LEAF AREA INDEX                   =  1.60
START OF GROWING SEASON (JULIAN DATE)     =   117
END OF GROWING SEASON (JULIAN DATE)       =   289
AVERAGE ANNUAL WIND SPEED                 =  8.80 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY     = 67.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY     = 48.00 %
```

AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 39.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 65.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SALT LAKE CITY UTAH

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.35	1.33	1.72	2.21	1.47	0.97
0.72	0.92	0.89	1.14	1.22	1.37

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SALT LAKE CITY UTAH

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.60	34.10	40.70	49.20	58.80	68.30
77.50	74.90	65.00	53.00	39.70	30.30

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SALT LAKE CITY UTAH

STATION LATITUDE = 40.76 DEGREES

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ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	12.09	6144138.500	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	6.673	3391262.750	55.20
DRAINAGE COLLECTED FROM LAYER 3	5.4249	2756949.000	44.87
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.182	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0007		
PERC./LEAKAGE THROUGH LAYER 7	0.222128	112885.211	1.84
CHANGE IN WATER STORAGE	-0.230	-116958.953	-1.90
SOIL WATER AT START OF YEAR	10.408	5289352.500	
SOIL WATER AT END OF YEAR	10.178	5172393.500	

SNOW WATER AT START OF YEAR	0.175	88898.516	1.45
SNOW WATER AT END OF YEAR	0.175	88898.516	1.45
ANNUAL WATER BUDGET BALANCE	0.0000	0.439	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	15.65	7953330.500	100.00
RUNOFF	0.134	68017.266	0.86
EVAPOTRANSPIRATION	9.626	4892161.500	61.51
DRAINAGE COLLECTED FROM LAYER 3	6.2333	3167757.750	39.83
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.036	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0008		
PERC./LEAKAGE THROUGH LAYER 7	0.143062	72704.148	0.91
CHANGE IN WATER STORAGE	-0.487	-247311.156	-3.11
SOIL WATER AT START OF YEAR	10.178	5172393.500	
SOIL WATER AT END OF YEAR	9.866	5013981.000	
SNOW WATER AT START OF YEAR	0.175	88898.516	1.12
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.530	0.00

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	10.33	5249706.000	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	5.762	2928023.750	55.78
DRAINAGE COLLECTED FROM LAYER 3	4.1638	2116055.250	40.31
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.136	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0005		

PERC./LEAKAGE THROUGH LAYER 7	0.104620	53167.801	1.01
CHANGE IN WATER STORAGE	0.300	152458.672	2.90
SOIL WATER AT START OF YEAR	9.866	5013981.000	
SOIL WATER AT END OF YEAR	9.221	4685910.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.946	480529.500	9.15
ANNUAL WATER BUDGET BALANCE	0.0000	0.526	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	18.28	9289896.000	100.00
RUNOFF	0.599	304522.125	3.28
EVAPOTRANSPIRATION	10.806	5491410.500	59.11
DRAINAGE COLLECTED FROM LAYER 3	6.7565	3433669.250	36.96
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.111	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0009		
PERC./LEAKAGE THROUGH LAYER 7	0.082204	41776.121	0.45
CHANGE IN WATER STORAGE	0.036	18520.076	0.20
SOIL WATER AT START OF YEAR	9.221	4685910.000	
SOIL WATER AT END OF YEAR	10.157	5161787.000	
SNOW WATER AT START OF YEAR	0.946	480529.500	5.17
SNOW WATER AT END OF YEAR	0.046	23172.334	0.25
ANNUAL WATER BUDGET BALANCE	0.0000	-1.530	0.00

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ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	12.76	6484631.500	100.00

RUNOFF	0.059	30046.072	0.46
EVAPOTRANSPIRATION	8.928	4537053.500	69.97
DRAINAGE COLLECTED FROM LAYER 3	4.4166	2244528.750	34.61
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.082	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0006		
PERC./LEAKAGE THROUGH LAYER 7	0.067151	34126.191	0.53
CHANGE IN WATER STORAGE	-0.711	-361120.969	-5.57
SOIL WATER AT START OF YEAR	10.157	5161787.000	
SOIL WATER AT END OF YEAR	9.492	4823838.500	
SNOW WATER AT START OF YEAR	0.046	23172.334	0.36
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-1.802	0.00

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ANNUAL TOTALS FOR YEAR 6

	INCHES	CU. FEET	PERCENT
PRECIPITATION	17.91	9101860.000	100.00
RUNOFF	0.097	49496.980	0.54
EVAPOTRANSPIRATION	10.890	5534425.500	60.81
DRAINAGE COLLECTED FROM LAYER 3	6.0368	3067885.750	33.71
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.101	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0008		
PERC./LEAKAGE THROUGH LAYER 7	0.056706	28818.016	0.32
CHANGE IN WATER STORAGE	0.829	421236.969	4.63
SOIL WATER AT START OF YEAR	9.492	4823838.500	
SOIL WATER AT END OF YEAR	10.321	5245075.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.027	13673.017	0.15
ANNUAL WATER BUDGET BALANCE	0.0000	-3.345	0.00

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ANNUAL TOTALS FOR YEAR 7

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.95	7597591.000	100.00
RUNOFF	0.005	2518.454	0.03
EVAPOTRANSPIRATION	9.806	4983538.500	65.59
DRAINAGE COLLECTED FROM LAYER 3	5.7670	2930768.750	38.57
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.106	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0007		
PERC./LEAKAGE THROUGH LAYER 7	0.048972	24887.602	0.33
CHANGE IN WATER STORAGE	-0.704	-357796.094	-4.71
SOIL WATER AT START OF YEAR	10.321	5245075.500	
SOIL WATER AT END OF YEAR	9.096	4622800.000	
SNOW WATER AT START OF YEAR	0.027	13673.017	0.18
SNOW WATER AT END OF YEAR	0.547	278152.656	3.66
ANNUAL WATER BUDGET BALANCE	0.0269	13673.754	0.18

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ANNUAL TOTALS FOR YEAR 8

	INCHES	CU. FEET	PERCENT
PRECIPITATION	12.22	6210204.000	100.00
RUNOFF	0.061	30803.779	0.50
EVAPOTRANSPIRATION	7.520	3821674.250	61.54
DRAINAGE COLLECTED FROM LAYER 3	4.2548	2162276.000	34.82
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.145	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0005		
PERC./LEAKAGE THROUGH LAYER 7	0.043137	21922.187	0.35
CHANGE IN WATER STORAGE	0.341	173526.609	2.79
SOIL WATER AT START OF YEAR	9.096	4622800.000	

SOIL WATER AT END OF YEAR	9.862	5012109.000	
SNOW WATER AT START OF YEAR	0.547	278152.656	4.48
SNOW WATER AT END OF YEAR	0.123	62370.070	1.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.437	0.00

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ANNUAL TOTALS FOR YEAR 9

	INCHES	CU. FEET	PERCENT
PRECIPITATION	17.05	8664811.000	100.00
RUNOFF	0.669	340151.500	3.93
EVAPOTRANSPIRATION	10.675	5425182.500	62.61
DRAINAGE COLLECTED FROM LAYER 3	6.3834	3244027.750	37.44
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.018	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0008		
PERC./LEAKAGE THROUGH LAYER 7	0.038300	19464.020	0.22
CHANGE IN WATER STORAGE	-0.716	-364016.875	-4.20
SOIL WATER AT START OF YEAR	9.862	5012109.000	
SOIL WATER AT END OF YEAR	9.269	4710462.000	
SNOW WATER AT START OF YEAR	0.123	62370.070	0.72
SNOW WATER AT END OF YEAR	0.018	9212.187	0.11
ANNUAL WATER BUDGET BALANCE	0.0000	1.641	0.00

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ANNUAL TOTALS FOR YEAR 10

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.16	7196113.000	100.00
RUNOFF	0.240	121737.211	1.69
EVAPOTRANSPIRATION	9.957	5059912.000	70.31
DRAINAGE COLLECTED FROM LAYER 3	3.5304	1794166.870	24.93

PERC./LEAKAGE THROUGH LAYER 5	0.000002	0.998	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0005		
PERC./LEAKAGE THROUGH LAYER 7	0.034486	17525.619	0.24
CHANGE IN WATER STORAGE	0.381	193557.766	2.69
SOIL WATER AT START OF YEAR	9.269	4710462.000	
SOIL WATER AT END OF YEAR	9.668	4913232.000	
SNOW WATER AT START OF YEAR	0.018	9212.187	0.13
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0181	9213.208	0.13

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ANNUAL TOTALS FOR YEAR 11

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.61	8441203.000	100.00
RUNOFF	0.022	11055.774	0.13
EVAPOTRANSPIRATION	9.395	4774535.000	56.56
DRAINAGE COLLECTED FROM LAYER 3	7.3727	3746784.750	44.39
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.188	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0010		
PERC./LEAKAGE THROUGH LAYER 7	0.031326	15919.972	0.19
CHANGE IN WATER STORAGE	-0.211	-107094.711	-1.27
SOIL WATER AT START OF YEAR	9.668	4913232.000	
SOIL WATER AT END OF YEAR	9.404	4779344.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.053	26792.830	0.32
ANNUAL WATER BUDGET BALANCE	0.0000	2.696	0.00

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ANNUAL TOTALS FOR YEAR 12

	INCHES	CU. FEET	PERCENT

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PRECIPITATION	13.10	6657419.500	100.00
RUNOFF	0.118	59907.531	0.90
EVAPOTRANSPIRATION	9.167	4658902.000	69.98
DRAINAGE COLLECTED FROM LAYER 3	4.2190	2144110.500	32.21
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.073	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0005		
PERC./LEAKAGE THROUGH LAYER 7	0.028753	14612.078	0.22
CHANGE IN WATER STORAGE	-0.433	-220112.328	-3.31
SOIL WATER AT START OF YEAR	9.404	4779344.500	
SOIL WATER AT END OF YEAR	8.848	4496509.000	
SNOW WATER AT START OF YEAR	0.053	26792.830	0.40
SNOW WATER AT END OF YEAR	0.176	89516.305	1.34
ANNUAL WATER BUDGET BALANCE	0.0000	-0.015	0.00

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ANNUAL TOTALS FOR YEAR 13

	INCHES	CU. FEET	PERCENT
	--------	----------	-------
PRECIPITATION	13.47	6845456.000	100.00
RUNOFF	0.058	29511.277	0.43
EVAPOTRANSPIRATION	7.761	3943984.750	57.61
DRAINAGE COLLECTED FROM LAYER 3	5.3262	2706780.500	39.54
PERC./LEAKAGE THROUGH LAYER 5	0.000002	0.960	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0007		
PERC./LEAKAGE THROUGH LAYER 7	0.026419	13426.176	0.20
CHANGE IN WATER STORAGE	0.299	151752.094	2.22
SOIL WATER AT START OF YEAR	8.848	4496509.000	
SOIL WATER AT END OF YEAR	9.278	4715227.000	
SNOW WATER AT START OF YEAR	0.176	89516.305	1.31
SNOW WATER AT END OF YEAR	0.044	22550.312	0.33

ANNUAL WATER BUDGET BALANCE	0.0000	1.415	0.00

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ANNUAL TOTALS FOR YEAR 14

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.01	7119883.000	100.00
RUNOFF	0.135	68528.242	0.96
EVAPOTRANSPIRATION	8.585	4362734.500	61.28
DRAINAGE COLLECTED FROM LAYER 3	4.9760	2528815.500	35.52
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.086	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0006		
PERC./LEAKAGE THROUGH LAYER 7	0.024480	12440.591	0.17
CHANGE IN WATER STORAGE	0.290	147360.984	2.07
SOIL WATER AT START OF YEAR	9.278	4715227.000	
SOIL WATER AT END OF YEAR	9.021	4584481.500	
SNOW WATER AT START OF YEAR	0.044	22550.312	0.32
SNOW WATER AT END OF YEAR	0.592	300656.812	4.22
ANNUAL WATER BUDGET BALANCE	0.0000	3.125	0.00

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ANNUAL TOTALS FOR YEAR 15

	INCHES	CU. FEET	PERCENT
PRECIPITATION	13.68	6952177.500	100.00
RUNOFF	0.108	54964.996	0.79
EVAPOTRANSPIRATION	8.100	4116242.750	59.21
DRAINAGE COLLECTED FROM LAYER 3	5.5005	2795336.250	40.21
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.033	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0007		
PERC./LEAKAGE THROUGH LAYER 7	0.022795	11584.607	0.17

CHANGE IN WATER STORAGE	-0.051	-25953.549	-0.37
SOIL WATER AT START OF YEAR	9.021	4584481.500	
SOIL WATER AT END OF YEAR	9.562	4859184.500	
SNOW WATER AT START OF YEAR	0.592	300656.812	4.32
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	2.476	0.00

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ANNUAL TOTALS FOR YEAR 16

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.35	7292669.500	100.00
RUNOFF	0.174	88545.336	1.21
EVAPOTRANSPIRATION	8.216	4175572.500	57.26
DRAINAGE COLLECTED FROM LAYER 3	6.1881	3144781.750	43.12
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.073	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0008		
PERC./LEAKAGE THROUGH LAYER 7	0.021372	10861.256	0.15
CHANGE IN WATER STORAGE	-0.250	-127093.133	-1.74
SOIL WATER AT START OF YEAR	9.562	4859184.500	
SOIL WATER AT END OF YEAR	9.311	4732091.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.951	0.00

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ANNUAL TOTALS FOR YEAR 17

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.02	7124966.500	100.00
RUNOFF	0.134	67864.836	0.95
EVAPOTRANSPIRATION	8.545	4342666.500	60.95

DRAINAGE COLLECTED FROM LAYER 3	4.9212	2500928.750	35.10
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.058	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0006		
PERC./LEAKAGE THROUGH LAYER 7	0.020006	10166.932	0.14
CHANGE IN WATER STORAGE	0.400	203337.828	2.85
SOIL WATER AT START OF YEAR	9.311	4732091.500	
SOIL WATER AT END OF YEAR	9.250	4700821.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.462	234607.906	3.29
ANNUAL WATER BUDGET BALANCE	0.0000	1.830	0.00

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ANNUAL TOTALS FOR YEAR 18

	INCHES	CU. FEET	PERCENT
PRECIPITATION	15.81	8034642.500	100.00
RUNOFF	1.135	576968.062	7.18
EVAPOTRANSPIRATION	9.378	4765732.000	59.31
DRAINAGE COLLECTED FROM LAYER 3	5.1903	2637711.500	32.83
PERC./LEAKAGE THROUGH LAYER 5	0.000002	0.993	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0007		
PERC./LEAKAGE THROUGH LAYER 7	0.018844	9576.649	0.12
CHANGE IN WATER STORAGE	0.088	44654.535	0.56
SOIL WATER AT START OF YEAR	9.250	4700821.500	
SOIL WATER AT END OF YEAR	9.799	4980084.000	
SNOW WATER AT START OF YEAR	0.462	234607.906	2.92
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.033	0.00

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ANNUAL TOTALS FOR YEAR 19

	INCHES	CU. FEET	PERCENT
PRECIPITATION	9.07	4609374.500	100.00
RUNOFF	0.231	117505.930	2.55
EVAPOTRANSPIRATION	5.883	2989654.750	64.86
DRAINAGE COLLECTED FROM LAYER 3	3.4629	1759835.000	38.18
PERC./LEAKAGE THROUGH LAYER 5	0.000002	0.999	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0004		
PERC./LEAKAGE THROUGH LAYER 7	0.017802	9046.771	0.20
CHANGE IN WATER STORAGE	-0.525	-266667.187	-5.79
SOIL WATER AT START OF YEAR	9.799	4980084.000	
SOIL WATER AT END OF YEAR	8.995	4571435.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.279	141981.781	3.08
ANNUAL WATER BUDGET BALANCE	0.0000	-0.900	0.00

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ANNUAL TOTALS FOR YEAR 20

	INCHES	CU. FEET	PERCENT
PRECIPITATION	18.14	9218749.000	100.00
RUNOFF	0.282	143199.062	1.55
EVAPOTRANSPIRATION	10.314	5241408.000	56.86
DRAINAGE COLLECTED FROM LAYER 3	6.1392	3119952.250	33.84
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.020	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0008		
PERC./LEAKAGE THROUGH LAYER 7	0.016914	8595.666	0.09
CHANGE IN WATER STORAGE	1.388	705591.687	7.65
SOIL WATER AT START OF YEAR	8.995	4571435.000	

SOIL WATER AT END OF YEAR	10.663	5419008.500	
SNOW WATER AT START OF YEAR	0.279	141981.781	1.54
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.836	0.00

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ANNUAL TOTALS FOR YEAR 21

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.37	7302835.500	100.00
RUNOFF	0.167	84939.570	1.16
EVAPOTRANSPIRATION	8.717	4430171.000	60.66
DRAINAGE COLLECTED FROM LAYER 3	7.1705	3644058.250	49.90
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.206	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0009		
PERC./LEAKAGE THROUGH LAYER 7	0.016017	8139.752	0.11
CHANGE IN WATER STORAGE	-1.701	-864477.000	-11.84
SOIL WATER AT START OF YEAR	10.663	5419008.500	
SOIL WATER AT END OF YEAR	8.808	4476467.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.154	78064.109	1.07
ANNUAL WATER BUDGET BALANCE	0.0000	4.081	0.00

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ANNUAL TOTALS FOR YEAR 22

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.01	8136283.000	100.00
RUNOFF	0.170	86612.898	1.06
EVAPOTRANSPIRATION	8.510	4324964.000	53.16
DRAINAGE COLLECTED FROM LAYER 3	5.9951	3046710.000	37.45
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.084	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0008		
PERC./LEAKAGE THROUGH LAYER 7	0.015247	7748.307	0.10
CHANGE IN WATER STORAGE	1.319	670245.750	8.24
SOIL WATER AT START OF YEAR	8.808	4476467.000	
SOIL WATER AT END OF YEAR	9.510	4832753.500	
SNOW WATER AT START OF YEAR	0.154	78064.102	0.96
SNOW WATER AT END OF YEAR	0.771	392023.781	4.82
ANNUAL WATER BUDGET BALANCE	0.0000	2.166	0.00

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ANNUAL TOTALS FOR YEAR 23

	INCHES	CU. FEET	PERCENT
PRECIPITATION	20.48	10407935.000	100.00
RUNOFF	1.423	723149.500	6.95
EVAPOTRANSPIRATION	10.949	5564125.000	53.46
DRAINAGE COLLECTED FROM LAYER 3	9.2962	4724336.000	45.39
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.213	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0012		
PERC./LEAKAGE THROUGH LAYER 7	0.014545	7391.994	0.07
CHANGE IN WATER STORAGE	-1.202	-611066.562	-5.87
SOIL WATER AT START OF YEAR	9.510	4832753.500	

SOIL WATER AT END OF YEAR	9.079	4613710.500	
SNOW WATER AT START OF YEAR	0.771	392023.812	3.77
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-1.061	0.00

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ANNUAL TOTALS FOR YEAR 24

	INCHES	CU. FEET	PERCENT
PRECIPITATION	15.44	7846608.500	100.00
RUNOFF	0.067	34202.121	0.44
EVAPOTRANSPIRATION	8.809	4476711.500	57.05
DRAINAGE COLLECTED FROM LAYER 3	6.0227	3060739.250	39.01
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.073	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0008		
PERC./LEAKAGE THROUGH LAYER 7	0.013939	7083.626	0.09
CHANGE IN WATER STORAGE	0.527	267871.187	3.41
SOIL WATER AT START OF YEAR	9.079	4613710.500	
SOIL WATER AT END OF YEAR	9.349	4751132.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.257	130449.023	1.66
ANNUAL WATER BUDGET BALANCE	0.0000	0.632	0.00

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ANNUAL TOTALS FOR YEAR 25

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.57	7404475.500	100.00
RUNOFF	0.159	80818.359	1.09
EVAPOTRANSPIRATION	9.657	4907882.500	66.28
DRAINAGE COLLECTED FROM LAYER 3	4.8777	2478866.500	33.48

PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.032	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0006		
PERC./LEAKAGE THROUGH LAYER 7	0.013308	6763.267	0.09
CHANGE IN WATER STORAGE	-0.137	-69860.836	-0.94
SOIL WATER AT START OF YEAR	9.349	4751132.500	
SOIL WATER AT END OF YEAR	9.290	4720989.500	
SNOW WATER AT START OF YEAR	0.257	130449.023	1.76
SNOW WATER AT END OF YEAR	0.179	90731.453	1.23
ANNUAL WATER BUDGET BALANCE	0.0000	5.548	0.00

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ANNUAL TOTALS FOR YEAR 26

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.10	8182020.000	100.00
RUNOFF	0.188	95593.625	1.17
EVAPOTRANSPIRATION	7.878	4003507.500	48.93
DRAINAGE COLLECTED FROM LAYER 3	8.5528	4346522.000	53.12
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.185	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0011		
PERC./LEAKAGE THROUGH LAYER 7	0.012763	6485.999	0.08
CHANGE IN WATER STORAGE	-0.531	-270090.500	-3.30
SOIL WATER AT START OF YEAR	9.290	4720989.500	
SOIL WATER AT END OF YEAR	8.937	4541630.500	
SNOW WATER AT START OF YEAR	0.179	90731.445	1.11
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.775	0.00

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ANNUAL TOTALS FOR YEAR 27

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.00	8131201.000	100.00
RUNOFF	0.045	22657.879	0.28
EVAPOTRANSPIRATION	9.249	4700380.000	57.81
DRAINAGE COLLECTED FROM LAYER 3	5.8141	2954737.500	36.34
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.142	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0007		
PERC./LEAKAGE THROUGH LAYER 7	0.012258	6229.550	0.08
CHANGE IN WATER STORAGE	0.880	447194.812	5.50
SOIL WATER AT START OF YEAR	8.937	4541630.500	
SOIL WATER AT END OF YEAR	9.329	4740811.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.488	248014.250	3.05
ANNUAL WATER BUDGET BALANCE	0.0000	1.446	0.00

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ANNUAL TOTALS FOR YEAR 28

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.69	8481860.000	100.00
RUNOFF	0.036	18489.059	0.22
EVAPOTRANSPIRATION	8.650	4395974.000	51.83
DRAINAGE COLLECTED FROM LAYER 3	8.3469	4241886.000	50.01
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.118	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0011		
PERC./LEAKAGE THROUGH LAYER 7	0.011823	6008.656	0.07
CHANGE IN WATER STORAGE	-0.355	-180499.781	-2.13
SOIL WATER AT START OF YEAR	9.329	4740811.000	

SOIL WATER AT END OF YEAR	9.124	4637057.500	
SNOW WATER AT START OF YEAR	0.488	248014.250	2.92
SNOW WATER AT END OF YEAR	0.337	171267.969	2.02
ANNUAL WATER BUDGET BALANCE	0.0000	2.514	0.00

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ANNUAL TOTALS FOR YEAR 29

	INCHES	CU. FEET	PERCENT
PRECIPITATION	16.66	8466614.000	100.00
RUNOFF	0.071	36178.352	0.43
EVAPOTRANSPIRATION	11.143	5662846.500	66.88
DRAINAGE COLLECTED FROM LAYER 3	5.7384	2916279.250	34.44
PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.055	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0007		
PERC./LEAKAGE THROUGH LAYER 7	0.011353	5769.445	0.07
CHANGE IN WATER STORAGE	-0.304	-154460.531	-1.82
SOIL WATER AT START OF YEAR	9.124	4637057.500	
SOIL WATER AT END OF YEAR	9.158	4653865.000	
SNOW WATER AT START OF YEAR	0.337	171267.969	2.02
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	1.001	0.00

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ANNUAL TOTALS FOR YEAR 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	12.38	6291517.000	100.00
RUNOFF	0.064	32732.117	0.52
EVAPOTRANSPIRATION	7.798	3962941.750	62.99
DRAINAGE COLLECTED FROM LAYER 3	4.4337	2253222.750	35.81

PERC./LEAKAGE THROUGH LAYER 5	0.000002	1.079	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0006		
PERC./LEAKAGE THROUGH LAYER 7	0.010948	5563.946	0.09
CHANGE IN WATER STORAGE	0.073	37053.020	0.59
SOIL WATER AT START OF YEAR	9.158	4653865.000	
SOIL WATER AT END OF YEAR	9.230	4690918.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.004	2190.594	0.03
ANNUAL WATER BUDGET BALANCE	0.0000	3.252	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.16	1.20	1.95	2.04	1.30	1.03
	0.69	0.85	0.84	1.05	1.31	1.46
STD. DEVIATIONS	0.60	0.54	0.77	0.87	0.68	0.74
	0.48	0.80	0.61	0.82	0.73	0.59
RUNOFF						
TOTALS	0.117	0.059	0.026	0.001	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.019
STD. DEVIATIONS	0.295	0.111	0.051	0.004	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.069
EVAPOTRANSPIRATION						
TOTALS	0.730	0.972	1.571	1.126	0.762	0.668
	0.467	0.511	0.476	0.499	0.483	0.647
STD. DEVIATIONS	0.129	0.228	0.502	0.488	0.469	0.452
	0.273	0.467	0.364	0.377	0.242	0.186
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.1083	0.1386	0.8686	1.0886	0.7423	0.4658
	0.3339	0.3104	0.2898	0.4400	0.5252	0.4388
STD. DEVIATIONS	0.3084	0.2275	0.5170	0.5566	0.3152	0.2377
	0.1927	0.2507	0.1949	0.4144	0.4035	0.3736

PERCOLATION/LEAKAGE THROUGH LAYER 5

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 7

TOTALS	0.0038	0.0034	0.0036	0.0034	0.0035	0.0033
	0.0033	0.0033	0.0031	0.0032	0.0030	0.0031
STD. DEVIATIONS	0.0049	0.0042	0.0045	0.0041	0.0041	0.0038
	0.0038	0.0036	0.0034	0.0034	0.0032	0.0031

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 5

AVERAGES	0.0002	0.0002	0.0013	0.0017	0.0011	0.0007
	0.0005	0.0005	0.0005	0.0007	0.0008	0.0007
STD. DEVIATIONS	0.0005	0.0004	0.0008	0.0009	0.0005	0.0004
	0.0003	0.0004	0.0003	0.0006	0.0006	0.0006

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	14.88 (2.435)	7561340.5	100.00
RUNOFF	0.222 (0.3270)	112690.58	1.490
EVAPOTRANSPIRATION	8.912 (1.3975)	4528853.00	59.895
LATERAL DRAINAGE COLLECTED FROM LAYER 3	5.75039 (1.40822)	2922348.750	38.64855
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00000 (0.00000)	1.086	0.00001
AVERAGE HEAD ACROSS TOP OF LAYER 5	0.001 (0.000)		
PERCOLATION/LEAKAGE THROUGH	0.04006 (0.04595)	20356.402	0.26922

LAYER 7

CHANGE IN WATER STORAGE	-0.047	(0.6766)	-23673.94	-0.313

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	1.66	843612.000
RUNOFF	1.276	648470.0620
DRAINAGE COLLECTED FROM LAYER 3	0.63349	321940.56200
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000000	0.00967
AVERAGE HEAD ACROSS LAYER 5	0.030	
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000803	408.13449
SNOW WATER	2.13	1082936.7500

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.2204
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1196

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	1.3240	0.2207
2	3.3548	0.1398
3	0.0032	0.0126
4	0.0000	0.0000
5	0.5250	0.7500
6	0.0018	0.0071
7	4.0217	0.1341
SNOW WATER	0.000	

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APPENDIX C

Post-Corrective Measures Ecological Risks at SWMU 12/15

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APPENDIX C
POST-CORRECTIVE MEASURES ECOLOGICAL RISKS AT SWMU 12/15

C.1 INTRODUCTION

Based on the results of the Revised Final Site-Wide Ecological Risk Assessment (SWERA) by Rust Environment and Infrastructure (E&I), 1997 performed at the Tooele Army Depot (TEAD), each solid waste management unit (SWMU) was characterized as either posing low, moderate or potentially unacceptable ecological risk. For those SWMUs characterized as posing unacceptable ecological risk, the SWERA recommended consideration of ecological risk reduction as part of corrective measures to be evaluated based on human health concerns. The purpose of this appendix is to outline the approach utilized in this CMS, and the results obtained in the evaluation of ecological risk under post-corrective measures activities for Known Releases SWMU 12/15, which were determined in the SWERA to pose potentially unacceptable ecological risks.

C.2 METHODOLOGY

The SWERA (Rust E&I, 1997) used both a "historic" and a "current" data set in the evaluation of ecological risk. The "historic" data set consists of data obtained through the Installation Restoration Data Management Information System (IRDMIS) database during the 1994 to 1995 time period. Because additional sampling has occurred since 1995 for some SWMUs, there may be differences between the data currently available for each SWMU and the historic data utilized in the SWERA. The "current" data set consists of data collected by Rust E&I for biotic and abiotic media at the reference study area (RSA, background site) and 10 SWMUs, including SWMU 12/15. Potential ecological risks were calculated in the SWERA using the "historic" and/or the "current" data sets for each SWMU.

Since the two data sets contain different types and amount of data, ecological risks were estimated in the SWERA using both sets of data independently. For the "historic" data set, ecological risks to various receptors were calculated based on the soil consumption route of exposure only. For the "current" data set, ecological risks to various receptors were calculated using a dynamic food chain model. Thus, risk estimates based on the "current" data set include both soil and prey consumption routes of exposure. For those SWMUs for which both "historic" and "current" data are available, two separate estimates of ecological risk were generated, and the higher risk level was utilized to characterize the risk identified at the SWMU.

To evaluate alternative corrective measures for SWMU 12/15 in this CMS (see Section 3), the post corrective measures risks are evaluated utilizing the methodology described in the SWERA to originally quantify the ecological risk. In general, this method involves the following steps:

- Identify all data utilized in the SWERA for each SWMU, and identify the main ecological risk drivers (those contaminants which contribute to the ecological risk) at each SWMU for each receptor.

- Identify the corrective measures to be considered at the SWMU.

- Identify those sample locations that will be affected as a result of each corrective measure.

- Estimate post corrective measure soil concentrations for each sample previously identified.

- Recalculate the SWMU soil concentration terms (C_{terms}) for the main risk drivers utilizing methods identified in the SWERA.

- Recalculate the hazards quotients and indices (HQs and HIs) for each receptor of concern at the SWMU utilizing the procedures identified in the SWERA. Compare the recalculated SWMU risk estimate to the RSA risk, and calculate the percent risk reduction associated with each corrective measure evaluated.

The method utilized to calculate ecological risk from the soil concentration (C_{term}) of a COPC is dependent on the source of the data used ("historic" or "current") to characterize the SWMU. For those sites in which the risk characterization is based on the "historic" data set, the hazard quotient (HQ) is calculated as:

$$HQ = \frac{C_{term} * SIR * AUF}{TBV}$$

where:

C_{term}	=	Recalculated soil concentration term for a selected COPC
SIR	=	Soil ingestion rate for the receptor of concern
AUF	=	Area use factor for the receptor of concern
TBV	=	Toxicity Benchmark Value for the receptor of concern

The soil ingestion rate, area use factor, and toxicity benchmark values were defined in the SWERA, and are used in this CMS without modification. The HI is calculated as the sum of all of the HQ values calculated for a specific SWMU.

The post-corrective measures ecological risks presented in Sections C.3.4 for SWMU 12/15 are based on the "historic" data set. For each corrective measures alternative considered in the CMS, the resulting post-corrective measures HIs have been calculated. These values of HI are compared in the following sections to the corresponding HI values for the RSA. The ecological risk estimates for each corrective measures alternative are then expressed in terms of the following two parameters: (1) the

RSA Multiplier, which is the ratio of the post-corrective measures HI to the HI for the RSA; and (2) the % Risk Reduction, which is the percent reduction in the value of post-corrective measure HI compared to the baseline value for the site. The results of these post corrective measures risk evaluations are then utilized in selection of the preferred corrective measures in Section 3 of the CMS for SWMU 12/15.

C.3 SANITARY LANDFILL/PESTICIDE DISPOSAL AREA (SWMU 12/15)

C.3.1 Introduction

Based on the evaluation of and levels of exposure to ecological receptors, the SWERA concluded that the contaminants detected in soil at SWMU 12/15 present a potential for unacceptable ecological risks. Specific factors considered in this risk characterization are as follows:

- Risk to passerine birds is estimated to be 2.3 times the ecological risks estimated for the reference study area. Primary risk drivers based on the historic data set are iron (21%) and chromium (62%). The primary risk drivers based on the current data set are copper (16%), dioxin (16%), and iron (16%).

- Risks to the deer mouse and jackrabbit are both estimated to be 1.5 times the reference study area risk. For deer mice, iron (35%) and copper (16%) are the primary risk drivers, and for jackrabbits, iron (34%) and RDX (14%) are the primary risk drivers.

- Risk to soil fauna is estimated to be 13.8 times the ecological risk estimated for the RSA. Risk to soil fauna is driven by chromium (55%), copper (20%) and iron (16%).

- For plants, risks are estimated to be 13.8 times the RSA risk. Polycyclic aromatic hydrocarbons (PAHs) (43%), copper (21%), and thallium (10%) are the primary risk drivers.

As noted above, the purpose of this section is to evaluate changes in ecological risk under post-corrective measure activities at SWMU 12/15. Specifically, changes in ecological risk to the passerine bird, deer mouse, and soil fauna as a result of reductions in soil that drive 5 percent or more of the risk are evaluated.

C.3.2 Ecological Risk Evaluation Strategy

The CMS Work Plan (Dames & Moore, 2000) indicated that corrective actions to be evaluated in the CMS Report for SWMU 12/15 will include some type of cap or cover. The post-corrective measures ecological risk assessments focus on any contaminant that contributes at least 5 percent of the estimated risk for at least one of the receptors under consideration. For SWMU 12/15, these contaminants include chromium, iron, lead, and zinc. Reductions in ecological risk are calculated based on post-corrective measure soil concentrations of these metals. In general, this method involves the identification of those sample locations affected as a result of each corrective measure, and recalculation of post-corrective measure soil exposure concentrations. Given this information, the risk to receptors of concern can be recalculated utilizing the methodologies presented in detail in the SWERA, and summarized in Section C.2 of this appendix.

C.3.3 Estimation of Post Corrective Measure Soil Concentrations

The SWERA utilized the “historic” data set in the evaluation of ecological risk at SWMU 12/15. The “historic” data set consists of data obtained through the IRDMIS database during the 1994 to 1995 time period. Ecological risk to various receptors were calculated based on the soil consumption route of exposure only.

The proposed corrective measures alternatives for soil at SWMU 12/15 are: 1) a multi-layer cap, 2) an evapotranspiration cover, and 3) improving the existing soil and vegetative cover. Alternatives 1 and 2 consist of completely covering the existing soil and vegetative cover, which reduces exposure to contamination in surface soil to background levels across the site. The soil samples that corrective measures alternatives 1 and 2 will affect are as follows:

- Corrective measures will be applied to reduce surface soil concentrations in a portion of the site designated by samples SS-1 through SS-30. These samples include all surface soil samples collected at SWMU 12/15.

- The corrective measure of landfill cover will result in post-corrective measure soil concentrations of all metals equal to background concentrations.

For those samples within the designated corrective measure area, post-corrective measure soil concentrations were substituted in the database for the original soil concentration. This resulted in a new soil database for SWMU 12/15 for the corrective measure considered. Based on this new database, the C_{term} (soil exposure term) was recalculated for each corrective measure.

Alternative 3 consists of improving the existing soil and vegetative cover without specifically addressing locations of identified ecological risk. The net effect is expected to benefit the ecological system, through development of healthy flora. The assumptions and approach described above cannot be used for Alternative 3.

C.3.4 Estimated Post Corrective Measure Ecological Risks

The post corrective measures values of HQ and HI are presented together with the corresponding baseline values in Tables C-1 through C-3 for passerine birds, deer mouse, and soil fauna, respectively. In addition, the calculated RSA Multiplier and percent Risk Reduction values for each corrective measures alternative are also presented in Tables

C-1 through C-3, which are at the end of this appendix. A summary of the calculated RSA Multiplier and percent Risk Reduction values is presented in Exhibit C-1 for each of the ecological receptors of concern.

Table C-1: Estimated Changes in Ecological Risk to Passerine Bird Receptors at SWMU 12/15

	Baseline Risk [1]		Corrective Measure [2]	
	SWERA		Waste Pile Removal	
Analyte	**Cterm [3]**	**HQ[4]**	**Corrective Cterm[3]**	**Measure HQ[4] Option 1**
Silver	1.89	0.109	7.75	0.448
Arsenic	27.62	1.420	32	1.646
Barium	205.7	1.527	291	2.160
Cadmium	4.36	4.830	1.33	1.473
Cobalt	238	0.204	9.63	0.008
Chromium/Hexachrome	**238**	**31.815**	**23**	**12.738**
Copper	339.1	4.415	39.9	0.519
DDT	0.033	0.238	0	0.000
Dioxin_Furan	2.03E-05	2.198	0.00E+00	0.000
Endosulfan	2.03E-01	0.552	0.00E+00	0.000
Iron	**24088.6**	**44.471**	**27,300**	**50.400**
Mercury	0.1689	0.049	0.1100	0.032
Nickel	9.83	0.243	26.50	0.656
Lead	**184**	**9.137**	**96.7**	**4.802**
PCB	0.105	0.378	0	0.000
Phthalate	1.19	0.082	0	0.000
Selenium	0.358	0.397	0.198	0.219
Zinc	**345.3**	**9.208**	**137**	**3.653**
HI[5]		211.270		78.76
RSA Multiplier[6]		2.340		0.87
% Risk Reduction[7]		NA		63%

1 Risk Calculated in SWERA.

2 Post Corrective Measure assumed to only affect Cd, Cr, Cu, Fe, Pb, and Zn soil concentrations only.

3 Cterm: Soil concentration term.

4 Hazard Quotient

5 Hazard indices calculated as the sum of Hazard Quotients.

6 Calculated as HI/RSA HI of 90.2

7 Risk Reduction = (90.2-HI)/90.2

Table C-2: Estimated Changes in Ecological Risk to Passerine Bird Receptors at SWMU 12/15

	Baseline Risk [1]		Corrective Measure [2]	
	SWERA		Waste Pile Removal	
Analyte	**Cterm [3]**	**HQ[4]**	**Corrective Cterm[3]**	**Measure HQ[4] Option 1**
Silver	1.89	0.001	7.75	0.005
Arsenic	27.62	0.192	32	0.223
Barium	205.7	0.46	291	0.65
Cadmium	4.36	0.046	1.33	0.014
Cobalt	7.83	0.866	9.63	1.065
Chromium/Hexachrome	**238.04**	**0.527**	**23**	**0.051**
Copper	339.14	1.912	39.9	0.225
DDT	0.033	0	0	0
Dioxin_Furan	2.03 E-05	0.54	0.00E+00	0
Iron	**24088.6**	**32.696**	**27300**	**37.056**
Mercury	0.168	0.005	0.11	0.003
Nickel	9.83	0.008	26.5	0.022
PAH	29.5	0.39	0	0
Lead	**184**	**1.224**	**96.7**	**0.643**
Phthalate	0.233	0	0	0
PCB	0.105	0.007	0	0
Antimony	11.38	0.504	1.45	0.064
Selenium	0.358	0.063	0.198	0.035
Vanadium	29.08	0.486	33.8	0.564
Zinc	**345.3**	**0.449**	**137**	**0.178**
HI[5]		41.7		40.8
RSA Multiplier[6]		1.468		1.437
% Risk Reduction[7]		NA		2%

1 Risk Calculated in SWERA.

2 Post Corrective Measure assumed to only affect Cd, Cr, Cu, Fe, Pb, and Zn soil concentrations only.

3 Cterm: Soil concentration term.

4 Hazard Quotient

5 Hazard indices calculated as the sum of Hazard Quotients.

6 Calculated as HI/RSA HI of 28.4

7 Risk Reduction = (28.4-HI)/28.4

Table C-3: Estimated Changes in Ecological Risk to Soil Fauna at SWMU 12/15

	Baseline Risk [1]		Corrective Measure [2]	
	SWERA		Waste Pile Removal	
Analyte	**Cterm [3]**	**HQ[4]**	**Corrective Measure Option 1 Cterm[3]**	**HQ[4]**
Arsenic	27.62	0.46	32	0.533
Cadmium	4.36	0.218	1.33	0.067
Chromium/Hexachrome	**238.04**	**595.1**	**23**	**57.5**
Copper	339.14	4.047	39.9	0.476
Iron	**24088.6**	**24.088**	**27300**	**27.3**
Mercury	0.168	0.168	0.11	0.11
Nickel	9.83	0.049	26.5	0.133
PAH	171	0.988	0	0
Lead	**184**	**0.304**	**96.7**	**0.16**
PCB	0.105	0	0	0
Selenium	0.358	0.005	0.198	0.003
Zinc	**345.3**	**1.727**	**137**	**0.685**
HI[5]		627.155		86.966
RSA Multiplier[6]		13.771		1.911
% Risk Reduction[7]		NA		86%

1 Risk Calculated in SWERA.
2 Post Corrective Measure assumed to only affect Cd, Cr, Cu, Fe, Pb, and Zn soil concentrations only.
3 Cterm: Soil concentration term.
4 Hazard Quotient
5 Hazard indices calculated as the sum of Hazard Quotients.
6 Calculated as HI/RSA HI of 45.5
7 Risk Reduction = (45.5-HI)/45.5

EXHIBIT C-1

Summary of Corrective Measures Risk Reductions for SWMU 12/15

Receptor of Concern	Risk Values	SWERA Baseline Risks	Corrective Measures Alternative Alternatives 1 and 2: Landfill Capping
Passerine Birds	RSA Multiplier % Risk Reduction	2.34 NA	87 63%
Deer Mouse	RSA Multiplier %Risk Reduction	1.5 NA	1.4 2%
Soil Fauna	RSA Multiplier % Risk Reduction	13.7 NA	1.9 86%

OLENE S. WALKER
Governor

GAYLE F. McKEACHNIE
Lieutenant Governor

Cf: File - Restoration
Larry McFarland
Tom Turner

TAT
3/16

State of Utah

Department of Environmental Quality

Dianne R. Nielson, Ph.D.
Executive Director

DIVISION OF SOLID & HAZARDOUS WASTE
Dennis R. Downs
Director

March 9, 2004

Tom Turner, Chief
Industrial Risk Management
Tooele Army Depot
Tooele, Utah 84074-5000

Re: Corrective Measures Study Report, SWMU 12/15, Sanitary Landfill/Pesticide Disposal Area, Tooele Army Depot, Tooele, Utah (EPA #UT3213820894)

DSHW Log No: 03.00940

Dear Mr. Turner:

We have completed our review of the subject report. All of our previous comments have now been addressed satisfactorily. We agree that Alternative 3, namely, improvements to existing soil and vegetative cover, groundwater monitoring, and land use restrictions, appears to address our concerns for the protection of human health and the environment. The report is hereby approved. Please prepare a corrective measures implementation plan for SWMU 12/15, according to the timelines specified in module VII of the TEAD post-closure and corrective action permit.

Thank you for your continuing and professional cooperation. If you have any questions, please contact Helge Gabert of my staff at 538-6001.

Sincerely,

Dennis R. Downs, Executive Secretary
Utah Solid and Hazardous Waste Control Board

DRD\HG\ts

c: Myron Bateman, M.P.H., R.S., Health Officer/Director, Tooele Co. Health Dept.
Rich Muza, USEPA Region VIII
Jim Kiefer, USEPA Region VIII
Larry McFarland, TEAD
Maryellen Mackenzie, U.S. Army Corps of Engineers, Sacramento
Carl Cole, U.S. Army Corps of Engineers, TEAD

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